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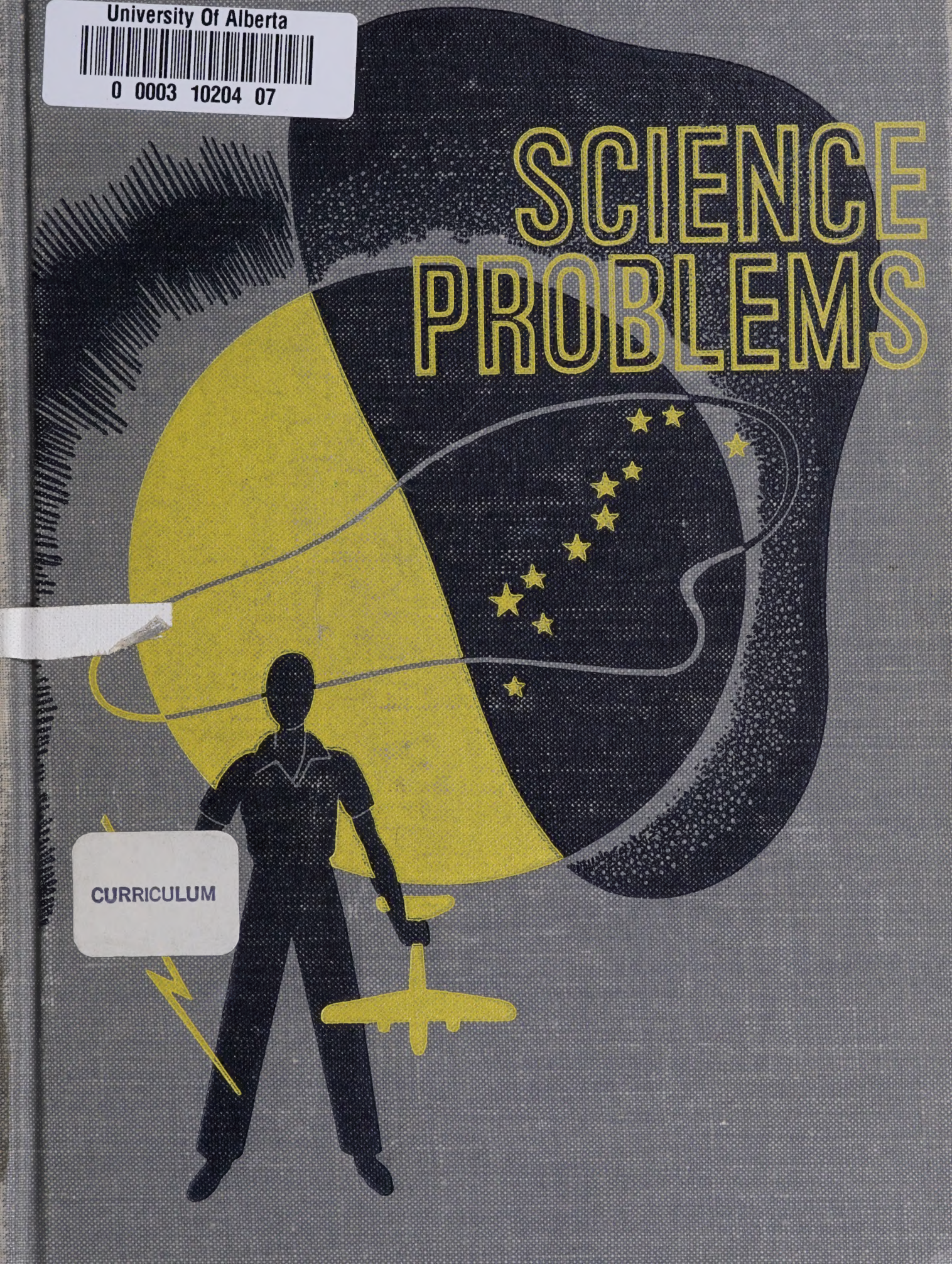

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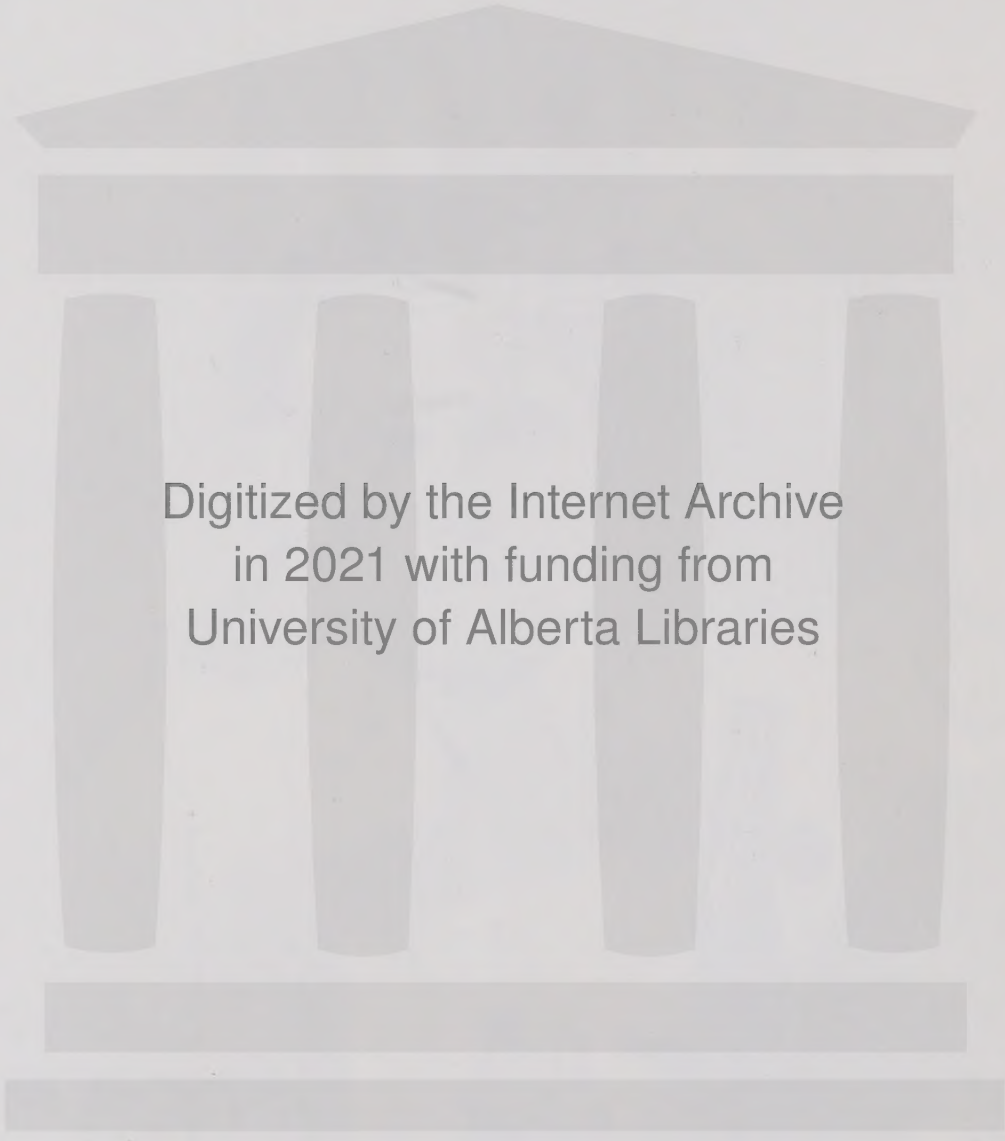
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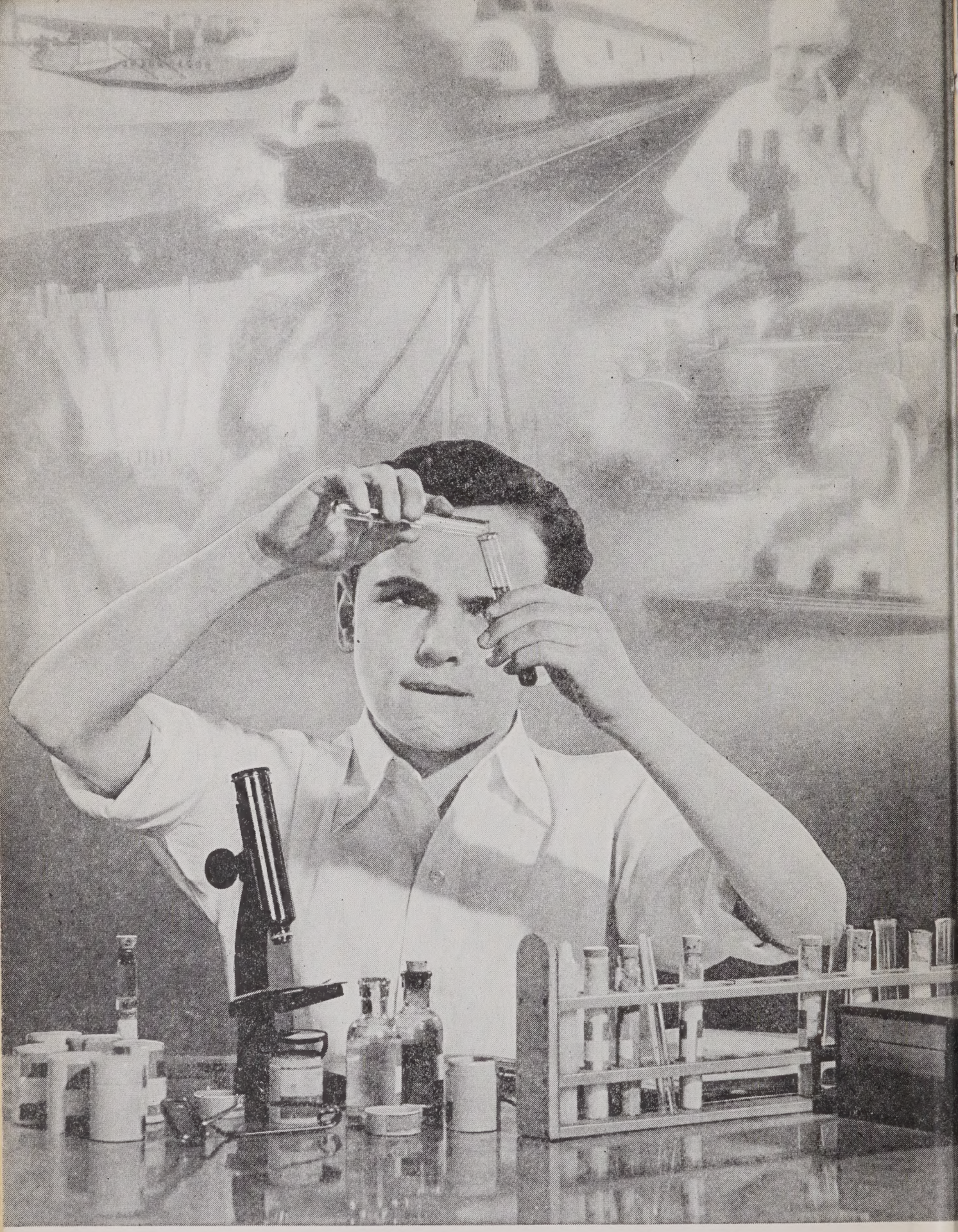

BASIC STUDIES IN SCIENCE

Science Problems

For the Junior High School

BY WILBUR L. BEAUCHAMP · *The University of Chicago*

JOHN C. MAYFIELD · *The University High School · Chicago*

JOE YOUNG WEST · *Maryland State Teachers College · Towson*

BOOK 1

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TO THE BOYS AND GIRLS WHO USE THIS BOOK*

YOU ARE just beginning a new course in science. We hope you are going to enjoy it and learn a great deal from it, because science includes the study of such very important things. But the way you go about your work in science is more important than what you learn.

As soon as you can, you should learn to do things without being told just what to do. Of course, you should be able to follow directions and do exactly what you are told. Thus, if the teacher tells you how to use this book, follow his directions very carefully. But sometimes your teacher may let you plan your own work, especially if you show that you can do it; or you may want to study ahead of the class, or do some units that the whole class is not studying. When you are studying "on your own," you can use the book better if you understand how the authors of the book intended that it be used. The paragraphs that follow tell how the authors would like to have you study.

At the beginning of each unit are some *Introductory Exercises.* These exercises will help you to recall ideas you already have that you will need in the study of the unit. They will also help you to begin thinking about the unit problem, because you will be looking for the answers to the exercises you cannot do. Write the answers in your science note-book under the proper title,

*Customary prefatory material addressed to the teacher will be found in the Teacher's Manual furnished free by the publishers.

such as "Unit One, Introductory Exercises." Number your answers to correspond with the numbers of the exercises. If there are some you cannot do, leave blanks for answers to be written later. It will be interesting to see how many you can do before you study the unit. Do your best, and write your answers neatly and clearly. Your note-book should be the record of all your work.

After you have done as many of the introductory exercises as you can, the teacher will "introduce" you to the unit problem or ask you to read the section, *Looking Ahead to the Unit.* Even though the teacher does tell you some interesting things about the unit, you will probably enjoy reading this section for yourself. It will help you to see clearly what the unit is about and why it is interesting. It will help you to see what you should understand when you have studied the whole unit.

With the introduction to the unit fresh in your mind, you will want to start right in to find the answer to the first problem. In each problem you will find reading material, pictures, *Self-Testing Exercises*, and *Problems to Solve.* Often there will be diagrams and directions for experiments. All of these will help you answer the problem. Be sure to look at the pictures carefully and read the descriptions below them. These descriptions often give interesting facts that you will not find in the regular reading material of the book.

As you read carefully through the problem, look up important words if you do not know what they mean or how to pronounce them. You will find a list of *Science Words*, beginning on page 415. This list tells how to pronounce the science words and explains what they mean.

Whenever possible, do the experiments. They will

help you understand and remember the important ideas you will use to answer the problems. Sometimes you will do the experiments in the classroom or laboratory with your classmates. However, you can do many of the experiments at home. If you do not have just the kind of apparatus the directions call for, you can often use something else or do the experiment in a different way if you understand what you are trying to find out.

Many of the main problems are divided into sub-problems. You will need to answer the sub-problems before you can give a complete answer to the main problem.

At the end of all problems and of some sub-problems you will find *Self-Testing Exercises.* These exercises are meant to be just what the name says. They are a way for you to test yourself, to see whether you understand and remember what the reading material, pictures, and experiments tell you. The exercises will be much better tests if you will try to do them without looking back in the book. After writing the answers as well as you can, it is a good plan to look back to be sure you are right, or to find the ideas you did not remember. When you have done all the *Self-Testing Exercises* that follow a problem, write the answer to the problem itself. Every pupil should do at least this much before going on to the next problem of the unit.

If you want to do more than is required, look at the *Problems to Solve.* These give you a real opportunity to show that you are learning, for the book does not give you the answers to these problems. To answer them you will need to use the facts and ideas you have gained by reading and doing experiments. Very often they are new applications of science principles that you have learned.

If you can answer these *Problems to Solve*, you may be sure that you have really learned the science principles. Some of the *Problems to Solve* call for gathering ideas from other experiments and other books. They will show whether you are learning to be an independent student. Probably very few pupils will have time to do all the *Problems to Solve*, but everyone should do some of them.

When you have finished your study of all the parts of a unit, turn back to the *Introductory Exercises* and answer those that you could not do when you began your study.

You should now be ready to do the *Summary Exercises*. These are to help you think back over the unit as a whole, to see its important ideas, and to find out if you understand the science words you have met.

If you finish the unit ahead of your class or if you have extra time outside of class, you will be allowed to do extra projects. You may do some of the *Additional Exercises* at the end of the unit, or you may read some of the books named in the list, *Readings in Science*, pages 411 to 414.

Talk with your teacher about your plans. He will often be able to suggest things to find out or to do about science in your own school or community. You can often help him, too, by finding things out for yourself and then telling the class what you have learned.

The real success of your work in science will be shown by: (1) how much you learn about science; (2) how well you can use what you learn; (3) how well you learn to work without being told just what to do.

Wilbur L. Beauchamp
John C. Mayfield
Joe Young West

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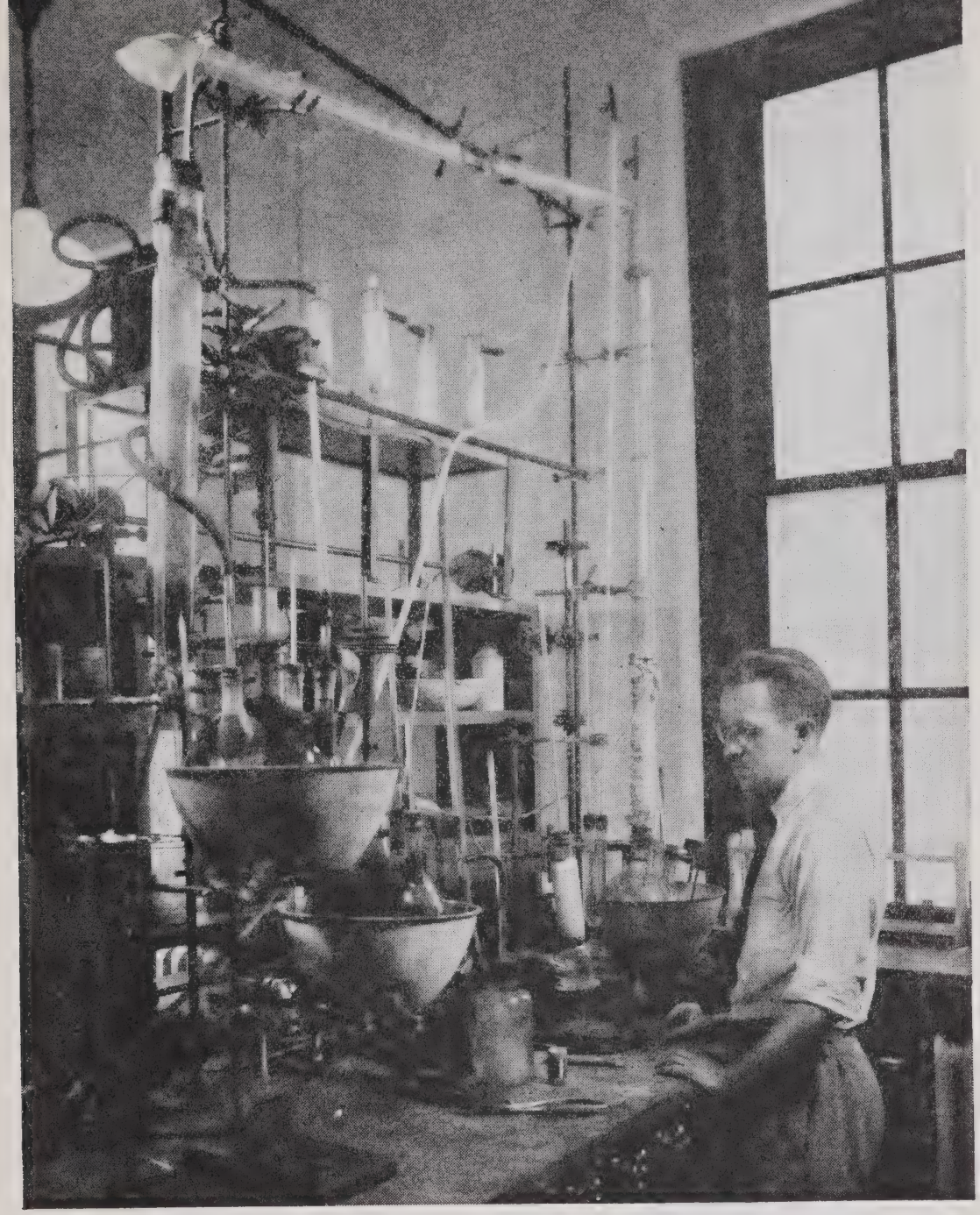


FIG. 1. This is just one corner of a large science workshop, or laboratory. The queer-shaped bottles, tubes, pans, and other apparatus do not mean much to you, but the scientist knows how to use them. In hundreds of laboratories like this one, scientists are at work every day solving problems and making discoveries about the world we live in. Do you know how a scientist works?

UNIT ONE

UNIT 1

HOW DO SCIENTISTS MAKE DISCOVERIES?

At the beginning of each unit of this book you will find introductory exercises. These exercises do several things. Some of them help you to check whether you understand certain big ideas that you will need as you study the unit. Others help you to remember experiences that may help you as you study. Still others check what you may already know about the unit. Answer these exercises as well as you can before you begin to study the unit.

INTRODUCTORY EXERCISES

1. Write a paragraph in which you explain as well as you can what the word *science* means to you.

2. Make a list of the problems you have solved today. Think of a problem as a situation in which you have to decide what to do. For example, perhaps you had to decide whether you would do the errands for your mother before or after school.

3. Select one of your problems from Exercise 2 and tell how and why you decided to do what you did.

4. What is an experiment? Tell of an experiment you have done to find out about something.

5. Why do scientists use experiments to help them solve their problems?

6. Name instruments that help us see, hear, feel, measure, etc., better than we could without them.

7. Make a list of some inventions that were not known in the time of George Washington.

8. The study of any school subject should help you to do certain things better. How do you think the study of science will help you?

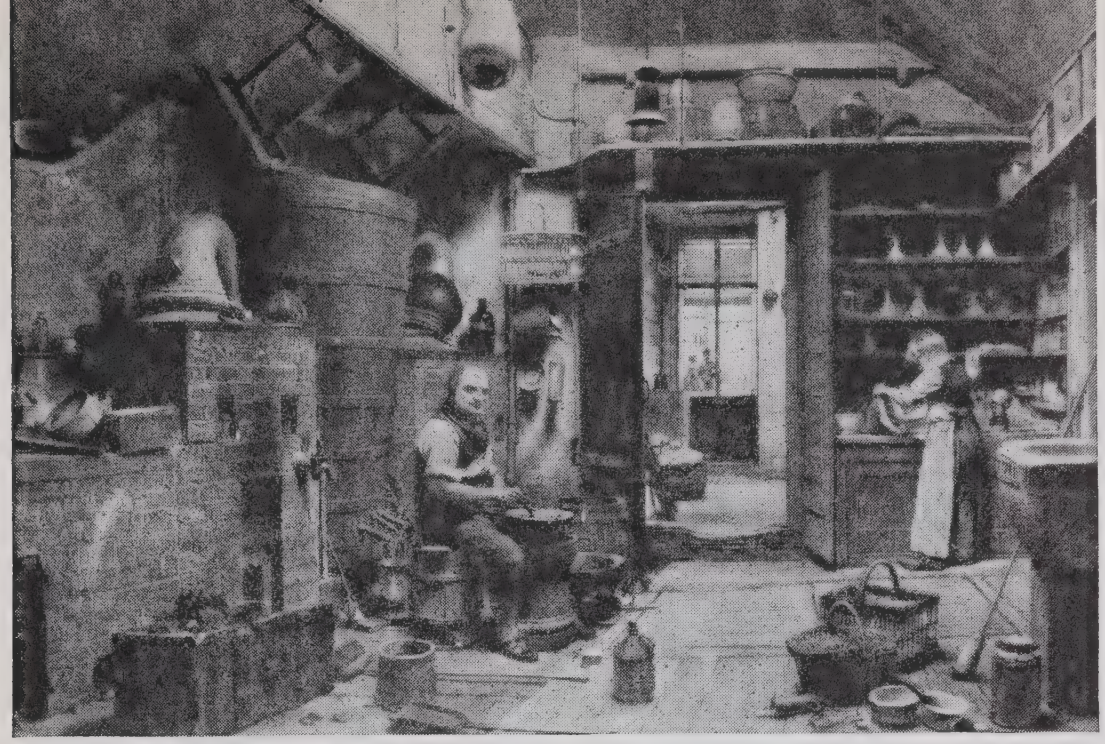


FIG. 2. This is the laboratory of Michael Faraday, a great British scientist who lived about one hundred years ago. As you can see, he did not have the wonderful instruments that modern scientists have, but he discovered many very important things about electricity. When he was a boy, Faraday cleaned dishes and pans for a scientist, just as the boy in this picture is doing for Faraday.

LOOKING AHEAD TO UNIT ONE

WHEN we think of a scientist today, we imagine a person surrounded with test-tubes, delicate measuring instruments, and bottles of strange substances. We see him bent over a microscope, carefully examining things that he could not see with his naked eyes. We see him in the chemical laboratory putting different substances together and taking other substances apart. These really are some of the things we would see if we visited a scientist at work today.

If we could watch a scientist at work two thousand years ago, how different the picture would be! Of course we would not find a laboratory full of wonderful instruments, because most of the things we find in a science laboratory today have been invented in the last hundred

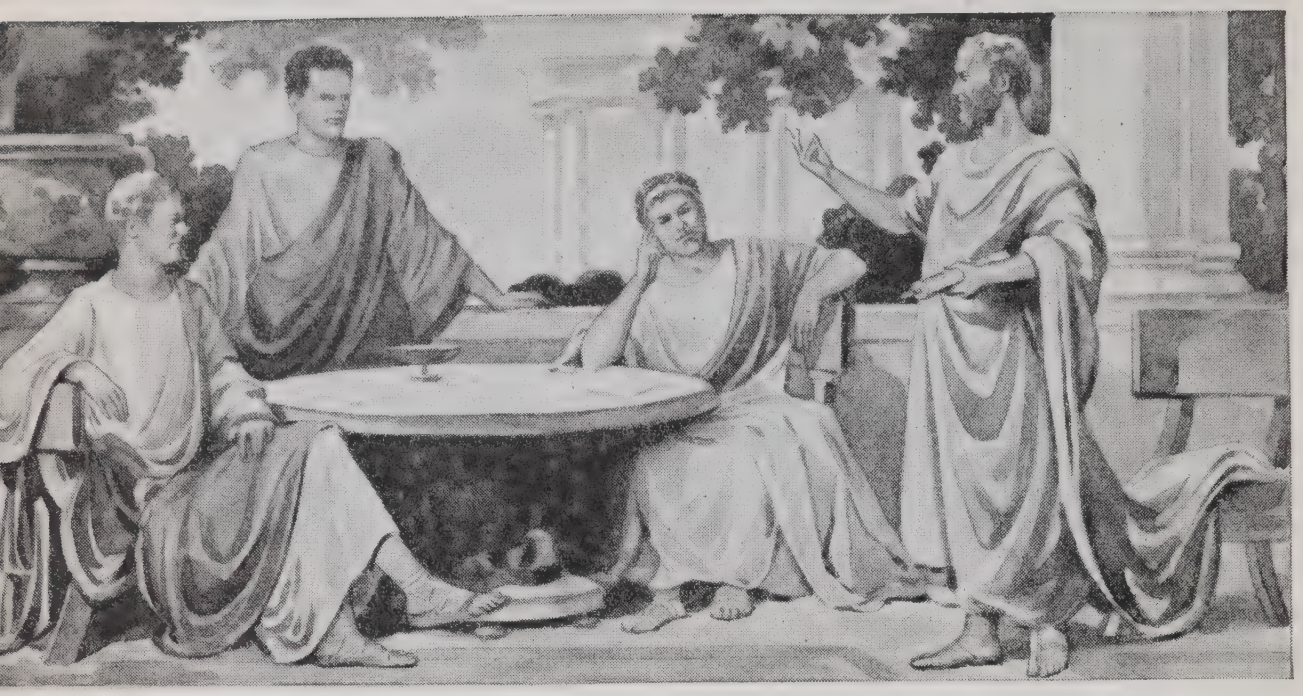


FIG. 3. Scientists of long ago met in groups like this to talk about the things that happened in the world. They had no laboratories for experimenting. They decided what was true by thinking about the things they saw instead of by experimenting to prove whether their ideas were right or wrong.

years. However, the absence of test-tubes, microscopes, and other modern apparatus would not be the most important difference. Two thousand years ago men were studying the world carefully and thinking about the things they saw. But they did not think in the same way that scientists of today think. They had not learned true scientific ways of finding the facts about the things they saw. Let us see how Aristotle, the famous Greek thinker, who lived over 2200 years ago, decided upon one of his ideas about nature.

Aristotle had noticed that a light object, such as a feather or a piece of paper, falls slowly to the ground, while a heavy object falls much faster. He thought this over and decided that heavy things fall faster than light

things; that is, a ten-pound weight will fall ten times as fast as a one-pound weight. Having decided this in his own mind, he taught it as a truth to his students. Because he was Aristotle, the wise man, his students believed him. You might think that Aristotle would have experimented to see whether heavy objects actually fall faster than light objects. But he did not do so. The early scientists never thought of experimenting. They would see something happen; then they would think about it and decide what it was or why it happened. But they never thought of testing their idea to see if it was true. For over 1700 years after his death Aristotle's ideas were accepted as the truth. No one doubted what he had said.

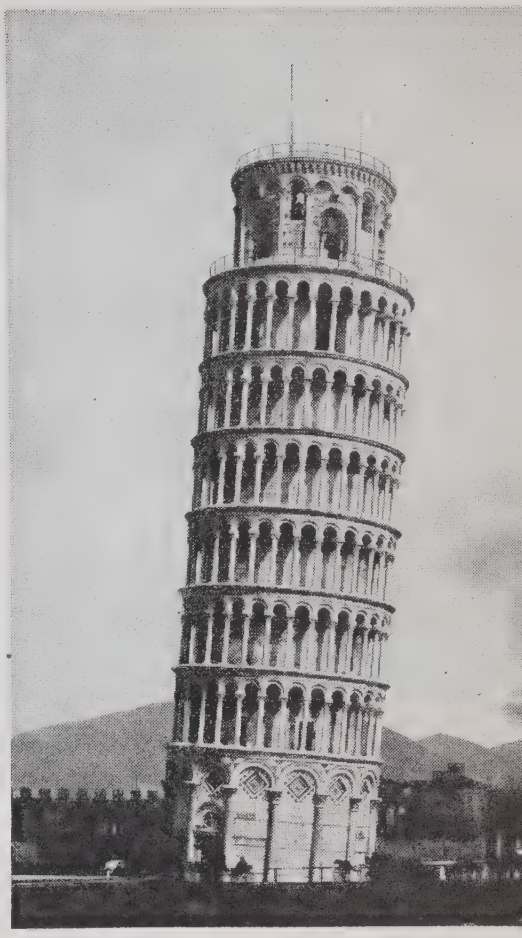


FIG. 4. The famous Leaning Tower of Pisa began to settle to one side after the first three stories were built.

It was a great day for science when a doubter came into the world—a man who did not believe everything he heard, a man who even doubted some things that the great Aristotle had said. This man was an Italian named Galileo, who lived 350 years ago. Among other things, he doubted whether heavy objects fall any faster than light objects.

But Galileo was a different kind of thinker from Aristotle. He was not sure he was right until he had tested his idea. To do this he dropped a small ball and a large ball from the top of the leaning tower in the city of Pisa.

FIG. 5. Galileo was so famous as a thinker that people came from far away to have him tell them about his discoveries.

Sure enough, they both hit the ground at the same time. He tried it again and again with other objects. At last he was sure that he was right. When Galileo told what he had learned, no one would believe him. Finally he persuaded a few men to come and see for themselves. Even then, they refused to believe what they saw with their own eyes. Because he would not believe some of the teachings of the great Aristotle, but thought things out for himself, Galileo was laughed at and even thrown into jail.

Today we praise Galileo and call him the father of modern science. He taught men how to think scientifically. He studied things carefully and described what he saw as accurately as he could. Then, instead of merely thinking out a reason for what he saw, he experimented to prove or disprove the truth of his ideas.

He refused to believe that a thing was true unless it had been proved to be true.

Now let us see just how scientists think and work. What is a "problem" in science? How do scientists find problems to solve, and how do they go at the job of solving them? What is an experiment? What marvelous instruments have scientists invented to help them in discovering the secrets of nature? These are some of the questions for which you will learn the answers in this unit.

As you study science this year, you will be asked to do some scientific thinking. You will want to understand what "scientific thinking" means. If you learn how the scientist works, and if you get the habit of working in the way that the scientist does, the study of science will make you a better thinker.

Problem 1:
HOW DO SCIENTISTS FIND PROBLEMS?

WHAT IS A "PROBLEM"? You have worked many arithmetic problems, and you know what they are. An arithmetic problem gives you some facts and asks you a question about the facts. You have to find the answer to the question. To find the answer you have to choose the right way to work the problem.

There are many other kinds of problems besides arithmetic problems. You have met and solved several of them already today. For example, suppose that as you started for school, you saw clouds piling up in the west. This made you think it might rain. You probably asked yourself this question, "Shall I wear my raincoat, carry an umbrella, or take a chance that it

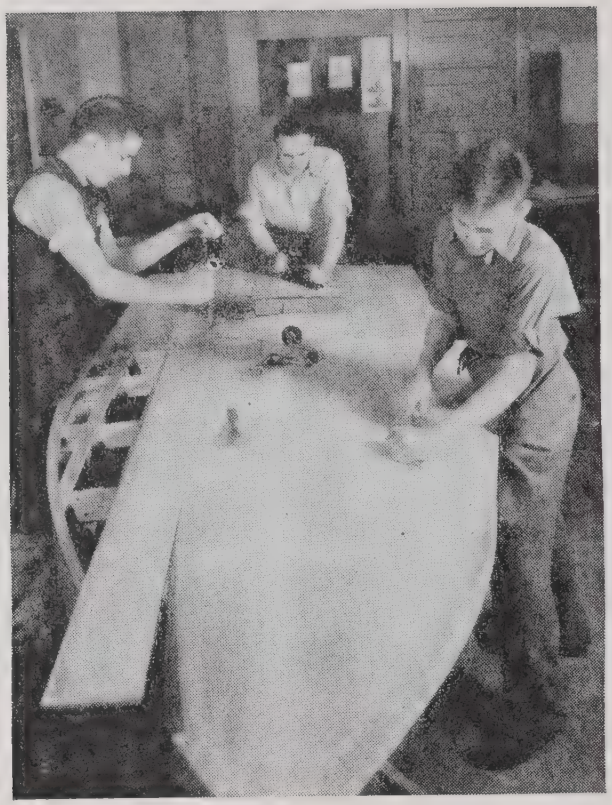


FIG. 6. These boys had to solve many problems while they were planning and building this boat. The first problem was, of course, what kind of boat they wanted. Can you think of some other problems they may have had to solve?

will not rain?" That was a problem to you. It was a problem to you because you did not know what to do. There were two or three different things you could have done. You wanted to choose the right thing to do.

Perhaps another problem you had to solve was whether you had time to go to your locker between classes. To solve the problem you considered how many minutes were left and how long it would take you to go to your locker and get what you wanted; then you decided whether you would have enough time.

Every day we all meet many different kinds of problems that we must solve. They are all alike, however, in one way: We are puzzled about something. We have to do something, but we do not know exactly what is the best thing to do. Or we want to know something, and we are not sure how to find out. In a science problem we are trying to find the answer to some question about the world we live in.

A scientist is just a human being like yourself. He has

the same everyday problems to solve that you have. Besides these problems of his own, he is keenly interested in the world we live in; he is always looking for an explanation of what he sees. He sees the sun rise and set, and he wonders why it appears in the east and disappears in the west. He pets a cat in the dark, sees sparks fly from the fur, and wonders what it is that makes the sparks. He sees smoke shoot from a distant cannon and a few seconds later hears the sound of the explosion. He wonders why he sees the smoke before he hears the noise. These are all problems to the scientist. He wants explanations for them, and he is not satisfied until he has good explanations.

Many people do not see anything to explain in the rising and setting of the sun, in sparks from cat's fur, and in the firing of a cannon. They are not interested in solving problems. They go through life with blind eyes and deaf ears. On every side they are surrounded with the wonders of the world. But they have no interest in what they see and hear. They are not like scientists.

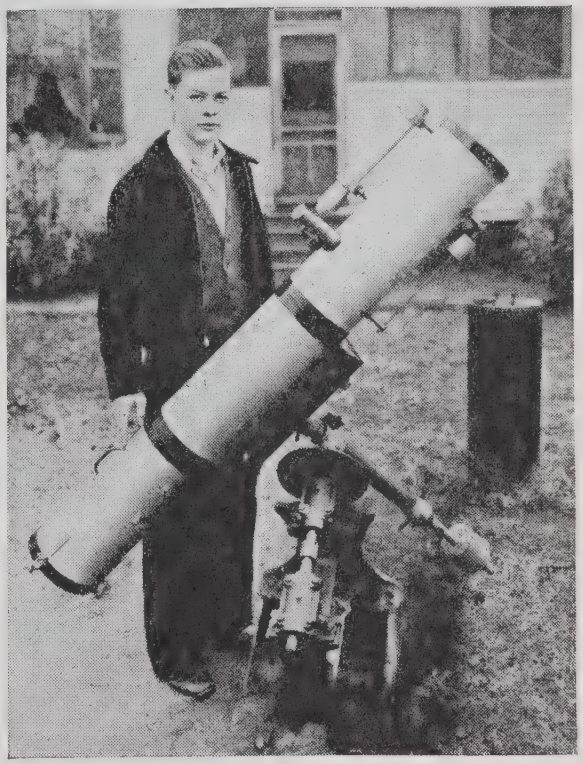


FIG. 7. Because Robert Lewis, a high-school student in Columbia, South Carolina, was interested in knowing more about the world, he made this telescope. With it he studied the sky and discovered a new star.

FIG. 8. These U. S. Government scientists are testing water from a stream in which the fish have been dying. Their problem is to find out whether the water has something in it that is killing the fish.

Scientists are always eager to find the "what," the "how," and the "why" of things. Scientists are "living question marks." They are always studying the world in which they live, and they are always discovering things they want explained.

WHAT KINDS OF PROBLEMS DO SCIENTISTS SOLVE? Scientists have always found plenty of problems to solve. To them this world has always seemed full of problems to solve. Why is there little rain on this side of the mountains and much on the other side? Why do the tides in the ocean rise so much higher at certain times of the year than at other times? Why does wood float, while iron sinks? Why do children usually look like their parents? These are the kinds of problems scientists have found and solved. No one had to ask them to

solve these problems. At first, perhaps, no one cared whether they did or not.

But, as the centuries rolled on, men and women came to understand and appreciate the great work of the scientists. Then they began to ask scientists to solve problems for them. For example, during the World War the shipment of troops and supplies from the United States to Europe was threatened by enemy submarines. When the submarine was under water, no one could tell that it was there. Something had to be done.

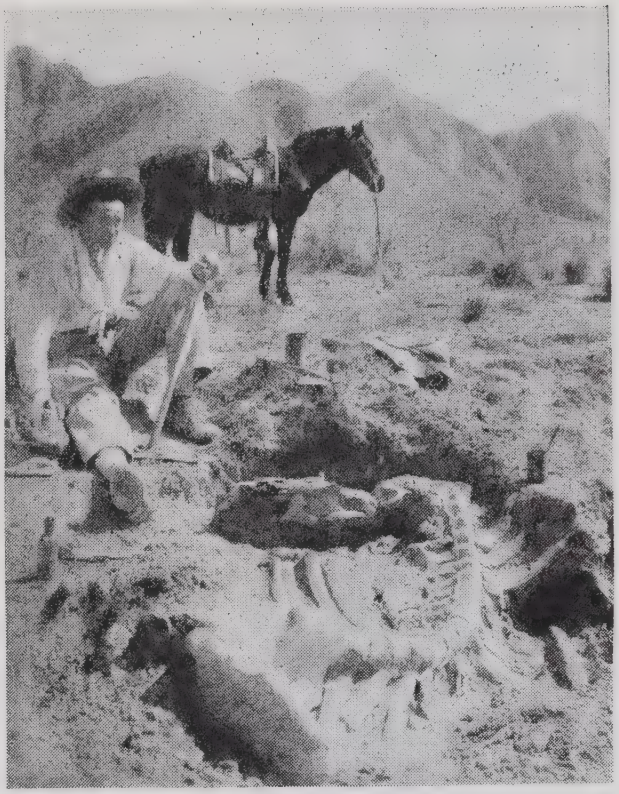


FIG. 9. There are many kinds of problems to solve and different kinds of scientists to solve them. This scientist is a *paleontologist*, who has just uncovered the hardened remains of an ancient animal. Paleontologists are scientists who study the earth to find out what kinds of plants and animals were living on the earth millions of years ago. (Field Museum)

The problem was given to a scientist, who finally invented an instrument called the "electric ear." This instrument could catch the sound made by the noise of the submarine's propeller. This strange "ear" also told the men on the ship how far away the submarine was, in which direction it was traveling, and how fast it was going.

Another interesting example of how scientists invent

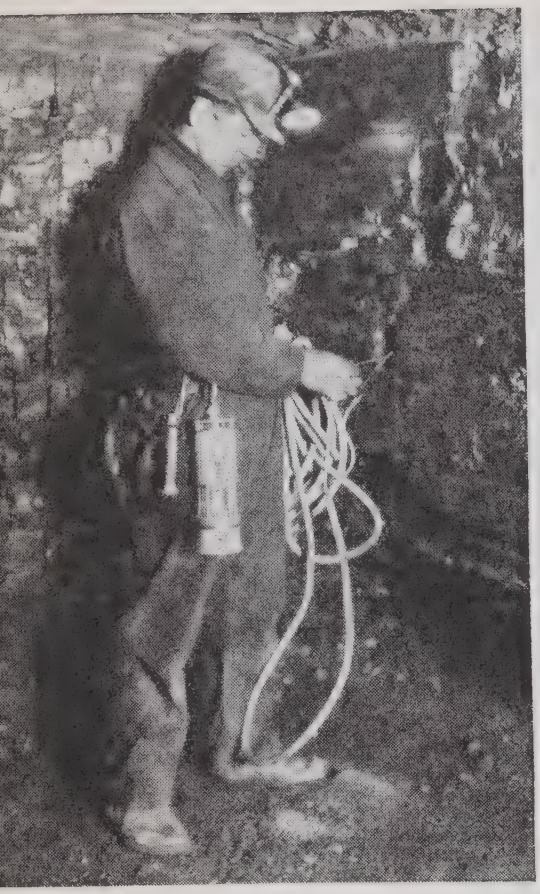


FIG. 10. The lamp hanging from the miner's belt is a modern Davy safety-lamp.

things that people need is the safety lamp used in mines. In England, years ago, miners found their way through the tunnels of coal mines with lighted candles. But dangerous gases collected in the mines, and the lighted candles often made the gases explode. So many miners were killed that men were not willing to risk their lives in mines. A scientist named Sir Humphry Davy was called upon for help. He took samples of the dangerous gas and experimented with it to find out what made it explode. Finally he invented a lamp that could be carried into the mines with perfect safety. These are but two examples of problems that scientists have been asked to solve.

Scientists have solved many health problems. One hundred years ago people suffered terribly during surgical operations. Many of them died afterward from inflammation in their wounds. Scientists discovered the *anesthetics* which put patients to sleep so that they feel no pain. Other scientists discovered the germs that caused the inflammation and learned how to kill them. Much suffering is prevented and many lives are saved every day because these problems were solved.

Every day scientists are trying to make new materials. They are needed to take the place of other materials that have become scarce and expensive. New materials are also needed to do and to make things in a better way

than some material we now use. For example, during your own life you have seen *Cellophane* largely take the place of tin-foil and paper for wrapping things. Artificial leather has taken the place of real leather for many uses. A steel that will not rust has been developed to make stainless steel knives and radiators for automobiles. For many purposes lacquers that dry in a few minutes are used instead of common paint that takes many hours to dry. Artificial silks, called *rayon* and *Celanese*, are made from wood or cotton and are used instead of silk for some purposes. All of these materials have been produced in scientific laboratories. Large manufacturing plants employ scientists to spend their whole time discovering new materials and new ways of doing things.

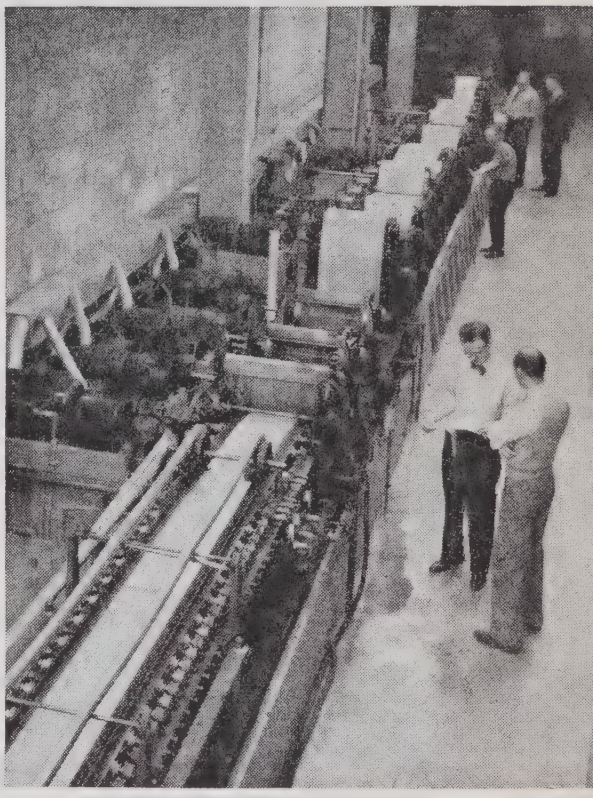


FIG. 11. This paper-making machine is in an experimental laboratory, where scientists study all kinds of products made from wood in order to improve them.

You must not get the idea that scientists and inventors will soon run out of problems to solve. Strangely enough, an invention that solves one problem may raise many new problems. The invention of the automobile, for example, made better roads necessary. Much experimentation has been carried on and is still going on to produce the best kind of road. Various kinds of traffic signals have been invented to make automobile travel safe. The invention of the automobile thus raised problems that have kept scientists

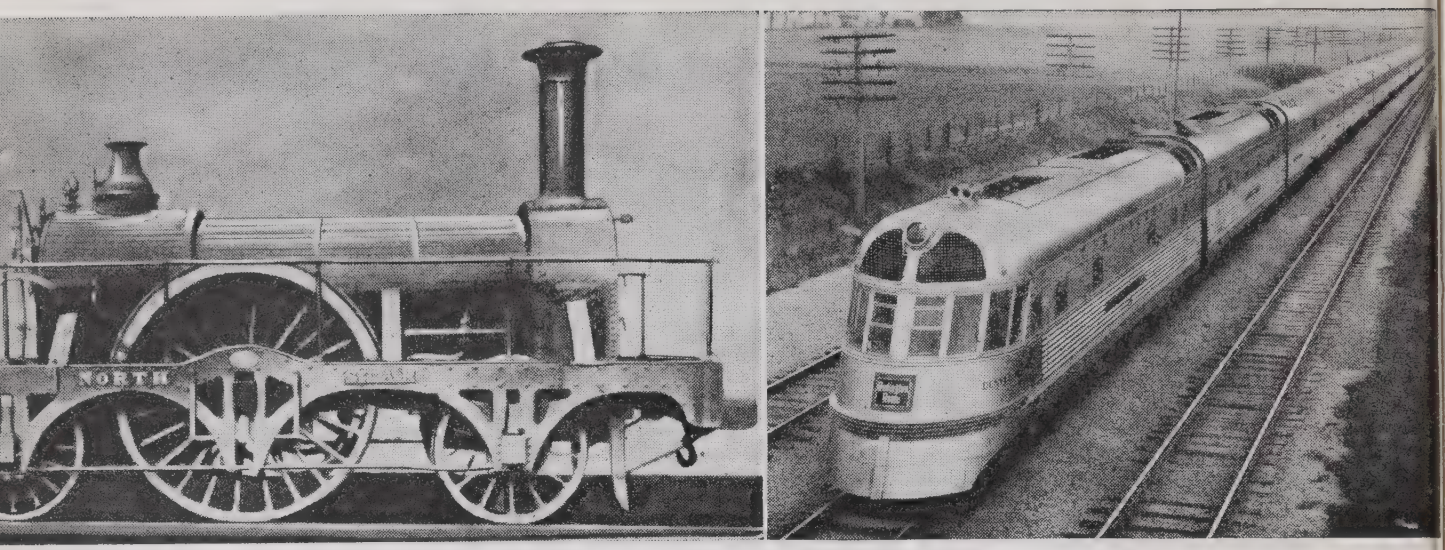


FIG. 12. Compare the early locomotive at the left with the streamlined train. Many problems had to be solved before men could build a locomotive that would pull heavy loads at high speeds. Men are still trying to improve locomotives.

busy for over forty years. And there are probably just as many more problems left to solve. If you are a good thinker and worker, you yourself may someday help to solve some of them.

Self-Testing Exercises

1. Explain what is meant by a "problem."

2. Give three examples of everyday problems that you are called upon to solve.

3. What kind of person do you think a scientist needs to be?

4. Make a list of five problems or kinds of problems scientists have helped to solve.

5. Do you think that there will ever be a time when we will not need scientists? Give good reasons for your answer.

6. Explain the difference between the way Aristotle decided what was true and the way Galileo decided what was true.

Problems to Solve

1. Give two examples to illustrate each of the following kinds of everyday problems you are called upon to solve.
a) Health problem. *Example:* What foods are best for me?
b) Social problem. *Example:* What kind of people do I want for my friends?
c) Science problem. *Example:* Our electric door bell will not work. What must be done to it to make it work?
d) Recreation problem. *Example:* Shall I read what I like, or what the teacher tells me is good literature?

2. Think of an example of your own to illustrate the idea that a new discovery or invention often brings new problems.

3. What are some of the ways in which scientists have helped solve the problem of how to keep food from spoiling?

4. What are some of the problems about airplanes that scientists are trying to solve?

5. Scientists have made wonderful discoveries about diseases and how to cure them. What problems do you suppose scientists have had to solve?

6. Try to find some problems that you think science can answer for you. For example, what are some problems concerning trees, automobiles, weather, houses, roads, birds, etc.?

Problem 2:
HOW DO SCIENTISTS SOLVE PROBLEMS?

YOU HAVE been reading about the kinds of problems that scientists solve. Now let us see how scientists solve them. You will need to know how a scientist thinks and works, because you will soon be solving some problems yourself. We shall first take a very simple problem and see how a scientific thinker would solve it.

Your best kite, one that flew perfectly, caught in a tree while you were pulling it down. Your problem is

FIG. 13. How can you get the kite out of the tree? What plans might you think of and then give up?

how to get it out of the tree. A number of ways of solving the problem come to your mind. Before doing anything about it, you think over these different ways and try to decide upon the best method to use. You decide that if you pull on the string, you will tear or break the kite. You are also sure that throwing sticks at it may tear the paper. So you give up these two methods without actually trying them.

There is a ladder in the garage at home, and you know just about how high the ladder will reach. Careful study of the distance from the ground to the kite shows you that the ladder is not long enough. You give that idea up, too. You think of climbing the tree. But the kite is out on the end of a limb, and you decide that the limb will not hold you up.

However, you see a big limb just above the one where the kite is. You decide that you can hold on to the

upper limb, and work your way out almost to your kite. Then perhaps you can shake the limb enough to jar the kite loose. This seems to be the best plan of all; so you decide to try it. You do try it, and it works. You have solved your problem.

Now perhaps you are wondering why this is an example of good thinking. Let us see the steps you used in thinking out your problem. In the first place, you knew exactly what it was you were trying to do. Of course, in this simple example the problem was easy to see. But many times it is very hard to know exactly what you are trying to find out.

Then you began to think of ways to solve your problem. A poor thinker very often fails at this point. He takes the first plan that comes to his mind and tries it out. If this plan does not work, he tries the next thing he thinks of, and so on. At last he either solves his problem or runs out of ideas. He wastes much time and may get himself into trouble. A good thinker does not work this way. He thinks of a number of possible ways of solving his problem. Instead of actually trying each plan as he happens to think of it, he studies each plan carefully to see if it is likely to work. He sees that some of the plans are not good; therefore he gives them up.

Finally the good thinker chooses a method that he believes will work. He then tries this method to see if it is the correct way to solve his problem. In other words, he *experiments* to discover whether or not his idea is correct. Experimenting is a way of testing our ideas. All scientists test their ideas by experiments before they are sure the ideas are true.

FIG. 14. Science has solved many problems to help us grow the plants we need for food. Growing corn on the same land every year cut the crop down to only twenty-three bushels per acre, shown at the right. But the land produced almost twice as many bushels per acre shown at the left, when the crops were changed every year.

Now let us take a problem in science to see just how a scientist thinks and works. Farmers used to raise the same crops year after year on the same land. Finally they noticed that their crops were getting poorer each year. They did not know why. They planted the seeds in the same way, but fewer of the seeds grew into good plants. This was a problem to be solved by a scientist.

The scientist thought of all the things that might keep the plants from growing. The poor crops might be caused by bad weather for a period of years. But the records of the weather bureau showed that the weather had not been unusually bad. Further investigation showed that when farmers used land where no crops had grown, the plants would grow very well for awhile; then after a few years the crop would again begin to fail.

Now the scientist knew that plants use certain minerals from the soil when they grow. He had learned this

FIG. 15. Needed minerals added to part of this field made the clover grow thick and tall. You can easily see where the soil did not have the necessary minerals.

by finding out just what materials the plants were made of. So he thought, "Perhaps the plants have used up the minerals in the soil, and that is why they won't grow." This seemed to be a good idea, but of course it had to be proved. How could it be proved?

If crops took minerals from the soil, there would be a difference between soil that had been used and soil that had not been used to grow crops. This idea could easily be tested. The scientist took a sample of soil that had been used and another sample of soil that had not been used. He tested these two kinds of soil to find what minerals were in them. He found that there was a difference. The unused soil had more of the minerals that plants need than the other soil had. The scientist seemed to be on the right track. But he still had not proved that the cause of the poor crops was the lack of minerals in the soil. How could he prove this?

If the cause of poor crops was lack of certain minerals, then the plants should grow better if these minerals were put in the soil. This sounded like good thinking, but

FIG. 16. Think of all the problems that have to be solved in growing food plants and raising animals on a farm like this. The soil must have the correct minerals in it. Both plants and animals must be kept from getting diseases and cured when they get diseases. Ways must be found to kill harmful insects. The farmer needs the scientist just as much as the manufacturer needs him.

the scientist could not be sure it was right just because it seemed to be a good idea. He had to experiment to test his idea. So he added the minerals to the soil, planted some seeds, and waited for the harvest. The result was just what he thought it would be. The plants grew well and produced a good crop. Now he was ready to believe that his idea was true. He had proved that the crops had failed because certain minerals were absent from the soil, and that crops would grow again if these minerals were added to the soil. This is the idea we use when we put fertilizers on soil to make it richer.

Now let us summarize what we have learned about the way the scientist thinks and works.

1. The scientist gets clearly in mind the problem he wants to solve. He sees clearly just what it is he is trying to do, or explain, or prove, or disprove.

2. He thinks of all the possible ways of explaining the facts he has found, or of solving his problem.

3. He chooses the explanation, or solution, that looks as if it might be the correct one.

4. He plans and tries an experiment to see if his explanation or solution is the correct one.

5. If the experiment seems to show that the explanation is a good one, he tests the explanation by other experiments to be sure that the solution is correct.

Scientists always *verify*, or prove, their results. Usually, when a scientist announces a discovery, he tells how he did the experiment and how he verified, or proved, his discovery. He does just what you do when someone says, "Well, how do you know it is true?" Other scientists test his results by repeating his experiments and by working out new experiments to prove his idea right or wrong.

A good scientist will never announce a discovery to the world until he has tested its truth in every way that he can think of.

Self-Testing Exercises

1. Close your book and make a list of the five steps scientists use in solving a problem. If you cannot remember them all, study until you can write them from memory.

2. What does the word *verify* mean?

3. Why are the discoveries that are announced by scientists likely to be true?

4. Give one important reason to show why scientists perform experiments.

5. On a full-size sheet of paper make a table like the one on the next page. Use plenty of room so that you can put

FIG. 17. Here are some student scientists at work in a school of forestry. They are learning how to take care of the valuable trees that give us food, lumber, and many other things that we need.

in all the five steps instead of just the first two. Then fill in the entire table. Do as much as you can from memory.

Steps in Solving a Problem Scientifically	Example of Kite in Tree (pp. 15-17)	Example of Crops that Did Not Grow Well (pp. 18-20)
(1) Decide exactly what the problem is.	To get the kite down without tearing it.	To find why plants do not grow well in the same field year after year.
(2) Think of all possible solutions.	Pull on string. Throw sticks, etc.	

Problems to Solve

1. Suppose you baked a cake, and it did not turn out well. What problem would this raise in your mind? How might you go about solving it?

2. John made a model airplane. When he attempted to fly it, he found that it would not rise from the ground. How could John go about solving the problem?

3. Many people believe that toads cause warts. How would you prove whether or not this is true?

4. Take some problem of your own and tell how you would solve it, using the scientific method.

Problem 3:

HOW HAVE SCIENTIFIC INSTRUMENTS HELPED SCIENTISTS SOLVE PROBLEMS?

WHEN we read of some of the things that people believed a few hundred years ago, we wonder how they could have believed them. You and all the others in your class know that the earth is ball-shaped and that it moves around the sun. Yet there was a time when the wisest men believed that the earth was flat and that all the heavenly bodies moved around the earth as a center. You know that frogs hatch from tiny eggs laid by the mother frog. But not so long ago men believed that frogs grew from the mud at the bottom of rivers and ponds. Two thousand years ago the wisest men thought that everything on the earth was made of four things: air, water, soil, and fire.

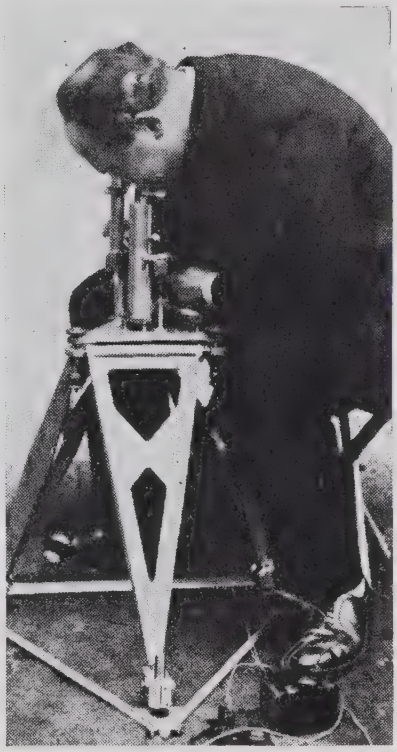


FIG. 18. For many years scientists have tried to find the weight of the earth. Now, with this delicate instrument, recently invented, they can determine the weight quite accurately.

But we must remember that scientists today have many helpers that scientists of a few hundred years ago did not have. These helpers are the marvelous instruments that men have invented. With these instruments men can weigh and measure and see and hear as they never were able to do before. Let us see how some of these instruments have helped solve problems.

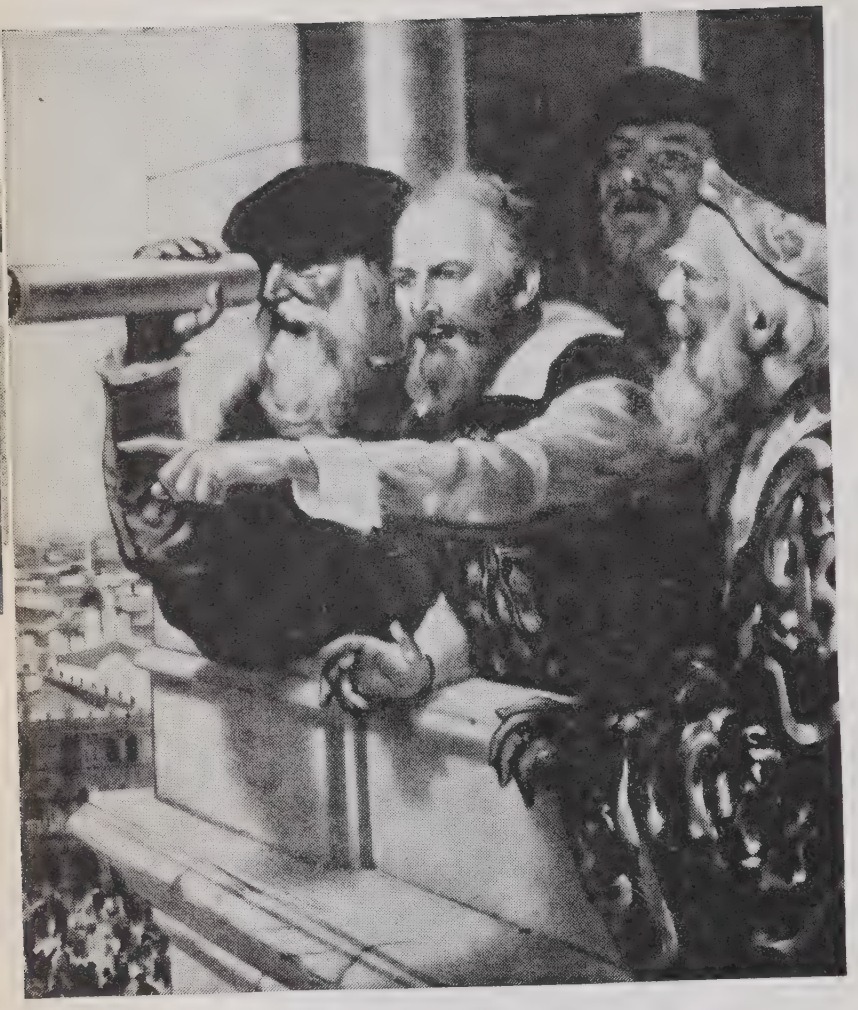


FIG. 19. From the top of a tower in Venice, Galileo is showing some of his friends how wonderful the telescope is. (Bausch & Lomb)

About 2200 years ago a man named Aristarchus told some of his friends that he thought the earth traveled around the sun. But no one believed he was right. About 1800 years later another wise man and careful thinker, named Copernicus, also came to believe that the earth was round. But still only a few thoughtful people here and there were willing to believe it. Almost everyone was sure the sun moved around the earth. But Galileo, about whom you read earlier in the unit, believed Aristarchus. Now, what these daring thinkers needed was some way of proving the truth of what they believed. They needed something that people could actually see with their own eyes; then, perhaps, people would believe what the scientists had discovered.

One day Galileo, down in Italy, heard that Johannes Lippershey, a spectacle-maker up in Holland, had invented a very interesting toy. When you looked through the glasses in this toy, things that were far away seemed to be near at hand. Lippershey had invented the *tele-*

scope, although he did not understand what a wonderful thing he had done. Galileo immediately started to make a telescope for himself. The first telescope he made would magnify three times, but finally he made one that would magnify thirty times. Then he turned this telescope on the heavens and saw things that no human being had ever seen before.

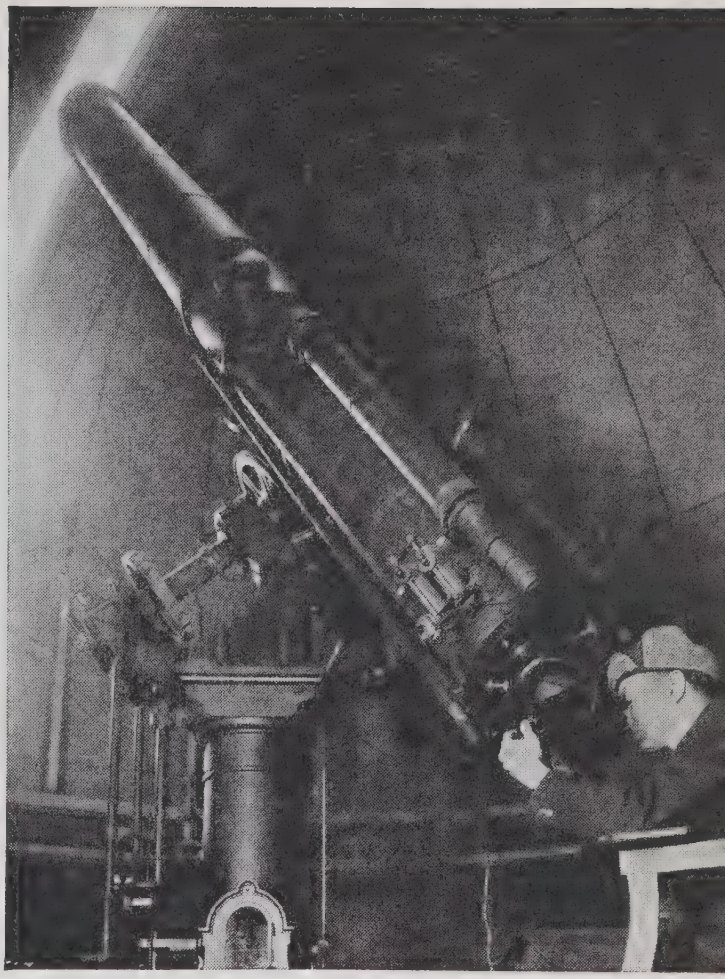


FIG. 20. Have you ever wondered how pictures of the moon and the stars are taken? This astronomer at the U. S. Naval Observatory in Washington, D. C., has attached a camera to the eyepiece of the telescope and is taking pictures of the stars and the planets.

One night, as he was studying the stars and planets, he noticed what appeared to be three little stars near the planet Jupiter. One star was on the right, and two were on the left. On another night he was surprised to find all three of the stars on the right. On still another night there were four of these little stars, three at the right and one at the left. At first he believed his eyes were fooling him, but more watching made him sure that the little stars were traveling around Jupiter.

Now of course this did not prove that the earth travels around the sun. But it showed that some of the heavenly bodies were revolving around Jupiter instead of around

FIG 21. About 250 years ago Anton van Leeuwenhoek, using a crude microscope that he had made, discovered the smallest of all plants, the *bacteria*. Later you will learn how important this discovery has been to each one of us. (Bausch & Lomb)

the earth. Therefore, the earth could not be the center of everything. With their own eyes men were now able to see that up in the vast spaces of the heavens things were different from what people had thought.

Since the invention of the telescope, scientists have constantly improved it. On Mount Wilson, in California, there is a telescope so powerful that through it you can see a light as small as that of a candle 5000 miles away. With your unaided eyes you can see about 5000 stars. With this giant telescope over 500,000,000 stars are brought into view. Without the telescope we would believe that we see all of the stars there are. But the telescope shows us that we cannot always trust our eyes. A new telescope is now being built that will make it possible to see stars over two hundred billion million miles away. Who knows how the things that will be seen through this new telescope will change our ideas about the heavenly bodies?

About three hundred years ago another scientific instrument was invented which, like the telescope, showed us how little we can really see. This instrument was the compound *microscope*. It was invented by a Dutchman, named Zacharias Janssen. For a long time almost no one ever used the microscope seriously, although a few scientists found it helpful in looking at insects. Of course the first microscope was a poorly made instrument. It would not show what our marvelous microscope of today will show. But it is hard to understand why it took men two hundred years to realize how important the instrument was.

FIG. 22. This scientist is using a powerful modern microscope to study things that no unaided eye could see. He is taking notes, and perhaps making drawings, so that he will have a record of the facts he is finding to help him solve some problem.

Imagine, if you can, the thrill that must have come to the scientist who first examined a drop of water and found it swarming with tiny animals. These animals were so small that they had to be magnified hundreds of times before they could be seen. This was one of the greatest discoveries ever made. It started scien-

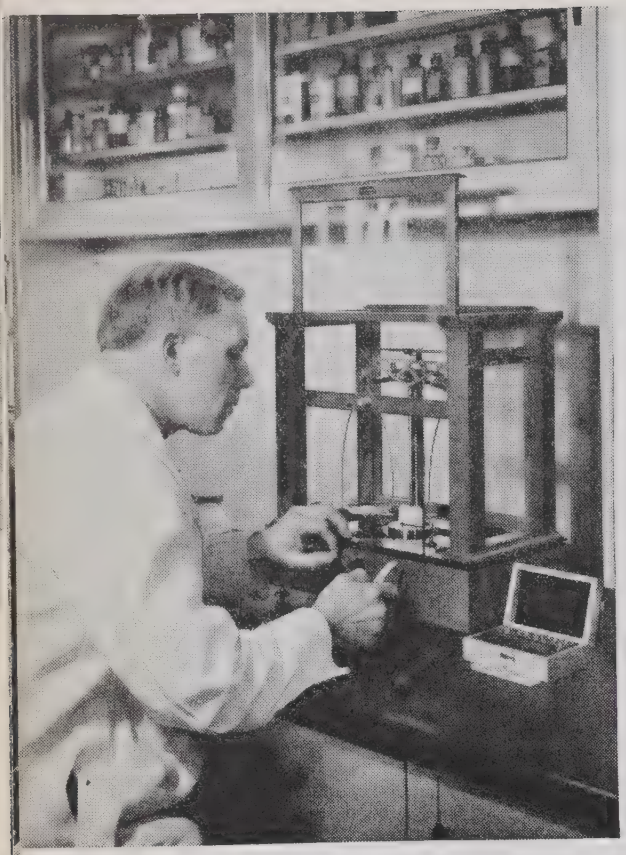


FIG. 23. This scientist is using an analytical balance. Notice how carefully he is handling the balance. In science work things must be measured exactly.

tists on discoveries which proved that many kinds of disease are caused by tiny plants or animals invisible to the naked eye. Once more the invention of a scientific instrument helped to solve problems that had been puzzling scientists for thousands of years.

Another instrument of great service in scientific discovery is the *analytical balance.* This is really nothing more than an extremely delicate pair of scales for weighing things. Some balances are so delicate that they will weigh the pencil marks you make when you write your name. The analytical balance has made possible many of the great discoveries about the materials of which things are made.

An even more sensitive instrument is the *spectroscope.* How the spectroscope works is too difficult to explain here. But by its use scientists have been able to discover the kinds of substances of which the sun is made. When you remember that the sun is over 90,000,000 miles away, you can well imagine how sensitive this instrument must be. The spectroscope and the telescope have told us most of what we know about the heavenly bodies. One interesting example of the use of the spectroscope was the discovery of a material that had never been known to exist. A

scientist, studying the sun one day with a spectroscope, found in the sun a strange material. It was unknown on earth. He named it *helium*, which means "sun element." Thirty years later another scientist was examining with the spectroscope a mineral that is common on the earth. He discovered helium in it. Later, helium gas was discovered in large quantities in a few places in the earth. Now it is used to fill dirigible balloons.

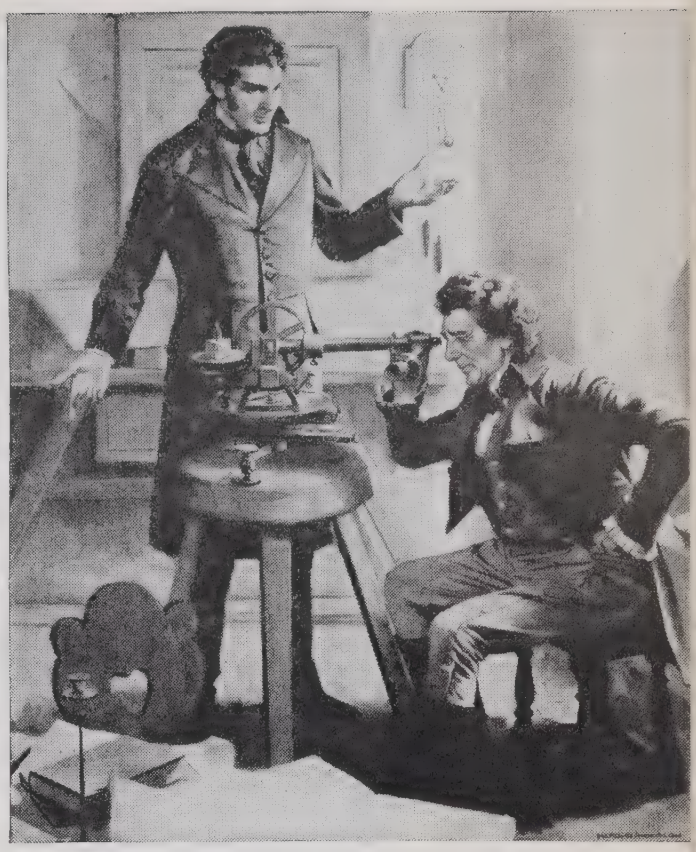


FIG. 24. Joseph Fraunhofer, a German, invented the spectroscope about 150 years ago. In this picture he is showing a friend how the spectroscope works. (Bausch & Lomb)

We use one of the instruments of science ourselves when we read the *thermometer* to tell temperature. However, most of the common thermometers are quite inaccurate. If they measure within a degree or two of the correct temperature, they are accurate enough for our everyday uses.

But the thermometers used by the scientist are much more accurate and delicate than the ones we use every day. Some of them are so sensitive that they can measure the heating effect of candles placed several miles away. They will even show a change in temperature if one of the candles goes out. Such thermometers are used largely to find out the temperature of distant stars and planets.

FIG. 25. With the stethoscope a doctor can hear what is going on in many of the inside parts of the body.

In the field of medicine scientific instruments are of the greatest value. The modern doctor listens to the beat of the heart with the *stethoscope*. This instrument also tells him important things about the condition of the lungs. He takes the body temperature with a *clinical thermometer*. He examines the organs and bones in the body by means of the *X-ray*. Under the microscope he examines blood to determine its condition and makes many other tests of the body. With these instruments he is often able to discover what is making the patient ill. When he understands what the disease is, he can work out ways of fighting it.

In spite of all that science has done for us, many people even today do not believe what scientists tell them. They believe only their own eyes and ears. They do not like to give up ideas they have believed for a long

time. But you have learned that our eyes and ears do not always tell us the truth about what we see and hear. A glass of water to the naked eye may appear perfectly pure. But a scientific experiment may show that it is full of disease germs. In your study of science you may find many things that are hard to believe. Remember, however, that science is tested knowledge. The true scientist has proved the truth of his discoveries by testing them to be sure that they are correct.

However, you will sometimes hear or read of things that are said to be proved by experiments. Many times such things are not true because the experiments were not reliable. A good knowledge of science will help you to tell the difference between true science and false science.

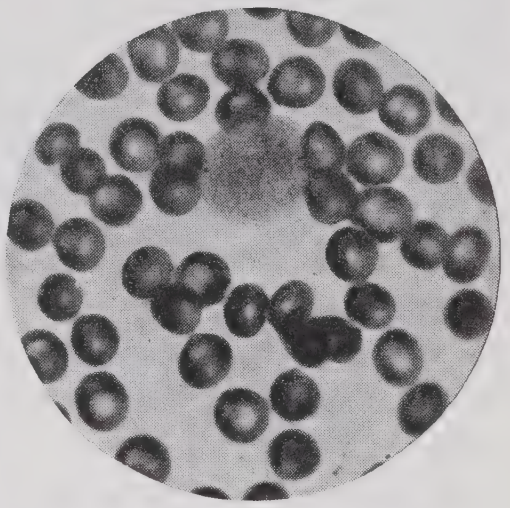


FIG. 26. The blood cells in your body look like this when they have been magnified 1000 times under a microscope. (General Biological Supply House)

Self-Testing Exercises

1. Why can the modern scientist discover more facts about the world than scientists of long ago could discover?

2. How does each of the following instruments help the scientist? Telescope, microscope, analytical balance, spectroscope, thermometer, stethoscope, X-ray.

3. Suppose a scientist writes an exact description of something. You look at the thing described, but it does not look like the same thing to you. Who is more likely to be correct, you or the scientist? Give reasons for your answer.

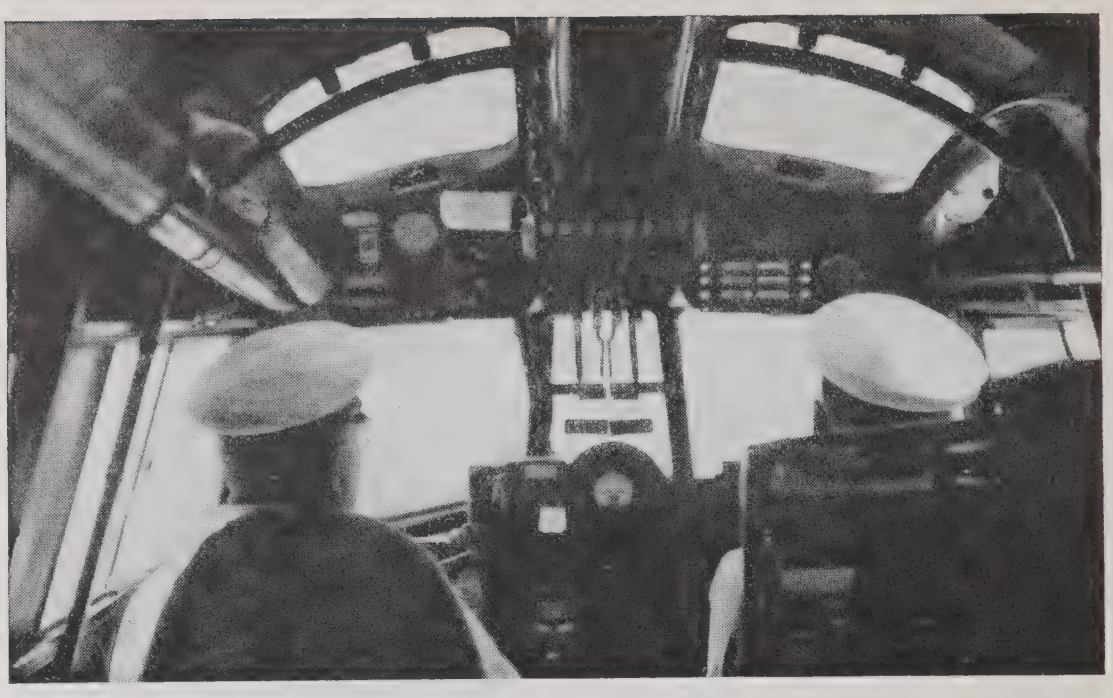


FIG. 27. Without the aid of many instruments the pilot of an airplane could never be sure of landing where he wanted to land. Do you know the names of some of the important instruments he uses?

Problems to Solve

1. Describe some ways in which a motion-picture camera might help the scientist solve his problems.

2. What instruments have you used to help you see, hear, weigh, and measure?

3. Describe the instruments that you have seen a physician use. What did he learn by the use of each instrument?

4. If you have had your eyes tested, tell what the doctor did to find out what kind of glasses you needed.

5. Look at some object with your naked eye; then look at it through a microscope or a reading glass. What did the instrument show you that you could not see without it?

LOOKING BACK AT UNIT ONE—SUMMARY EXERCISE

Write a one-page theme that answers the problem of this unit—How Do Scientists Make Discoveries? Be sure to include all of the most important ideas you have gained by reading the unit.

FIG. 28. This X-ray picture of a foot in a shoe shows very plainly the bones and the metal portions of the shoe. Some shoe stores have X-ray machines through which a person looks to see whether or not a pair of shoes fits his feet.

ADDITIONAL EXERCISES

1. From the reading list at the back of this book, choose biographies of several scientists. Read them. How did the scientists get started in scientific work? What discoveries did they make? How did they solve their problems? In what ways did their discoveries change our way of living?

2. Keep a scrapbook in which you record new inventions and discoveries. You will find articles in daily newspapers. You will also find reports of discoveries in magazines, such as *Time*, *News-Week*, *Scientific American*, *Popular Mechanics*, and others.

3. Obtain automobile folders and list the improvements that have been made in the past year. You can make an interesting study of the development of automobiles by looking at advertisements in magazines for a period of years, noting the improvements mentioned for each year.

4. Select one of these inventions and from reference books find all you can about the inventor and how he worked out the invention: telescope, microscope, X-ray, thermometer, spectroscope.

5. Obtain two packages of bean seeds from two different seed companies. Write the directions for performing an experiment that will show which package of seeds is the better. Then do the experiment. What did you discover?

6. Visit the county farm agent. Find out from him how he determines the kind of fertilizer that a farmer needs for his field.

7. Suppose you were going to buy a vacuum bottle. The dealer has two bottles that look very much alike, but one costs considerably more than the other. The dealer tells you the cheap one is just as good as the expensive one. How could you find out if this is true? If you can do so, get two vacuum bottles and try your experiment.

8. If there is a factory near you, visit it and find what scientific instruments are used.

9. You have probably noticed that the sun appears lower down in the sky in the winter than in the summer. How could you prove that your observation is correct, using only a ruler? Try your experiment.

10. How would you find out whether the direction of the wind will tell you if it is going to rain. Test your plan. What do you discover?

11. Usually when a scientific discovery is made, reporters talk to some other scientists to learn what they think about the discovery. After some discovery is announced, watch the papers and see what the other scientists say. If they accept it as true, why do they accept it? If they withhold their judgment as to whether it is true, what reasons do they give?

12. Read *Microbe Hunters* or *Hunger Fighters*, by Paul de Kruif, to learn about some real scientific problems and how they were solved.

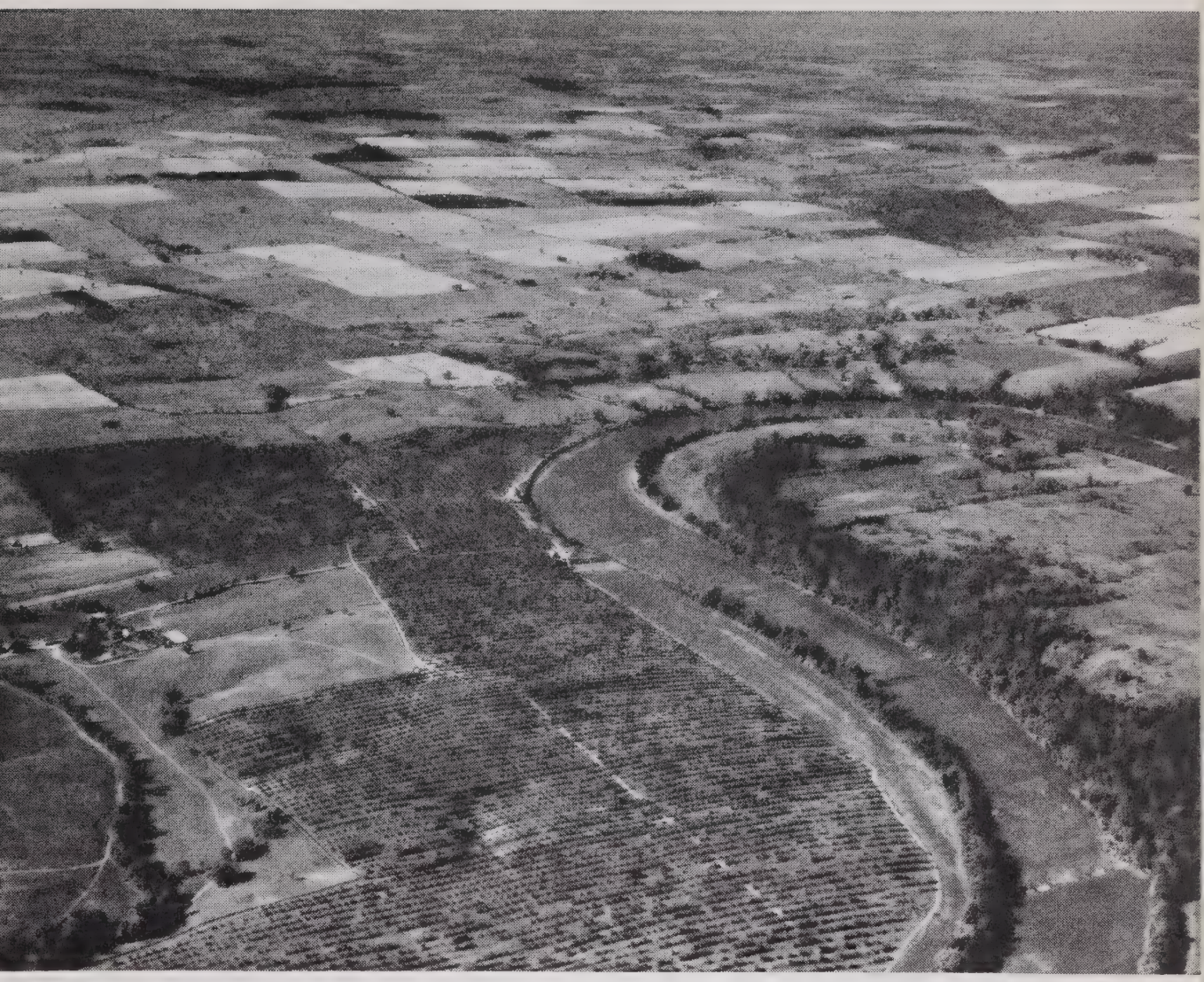


FIG. 29. Even from an airplane we can see only a tiny part of the world we live in. But that small part can furnish us with countless interesting problems to solve. You could spend a life time studying nature in and around the place where you live.

UNIT TWO

UNIT 2

WHAT KIND OF WORLD DO YOU LIVE IN?

INTRODUCTORY EXERCISES

1. Write a short description of the earth. What facts have you learned for yourself about the part of the world where you live? What other facts have you learned about the earth from books?

2. Make a list of ten materials that man uses to make things.

a) After each material, state several things made of it.

b) Tell whether each material you have on your list is made by man or used as he finds it in or on the earth.

3. Make a list of ten different kinds of plants you have seen.

4. Make a list of ten different kinds of animals you have seen.

5. Everything that moves is either pulled or pushed by a force. For example, your muscles can move things. Name all the forces you can.

6. What things can man do that no other living things can do? Why can he do these things?

FIG. 30. These girls are interested in the other living things in the world around them. They are finding the names of wild flowers. What shows you that they are solving their problem in a scientific way?

LOOKING AHEAD TO UNIT TWO

YOU already know many facts about the world you live in. For at least ten years you have been watching what is going on around you. It is doubtful, however, if you have explored the world very thoroughly. Of course, the best way to explore is to see and do things yourself. But you do not have a magic carpet to take you everywhere you want to go; so you may do some of your exploring in the next best way: You may listen to others tell of their experiences and read what others have discovered.

In your science study you will learn many of the things that scientists have discovered about the world, and you

FIG. 31. Some parts of our world are almost level, as you see in Figure 29. Other parts are rocky and mountainous. Some parts are dry and barren; others have plenty of rain and are covered with plants. Scientists have solved many problems that explain why *conditions* are so different in different parts of the world.

will understand better many things that you see happening every day.

To get you off to a good start in your science explorations, this unit of the book will give you a big picture of the kind of world you live in. This big picture will help you to see where you are going in your science work. It will show you briefly what science is and what interesting discoveries scientists are making about the world we live in.

For thousands of years men and women knew very little about the world. But as time went on, they began to study it more and more carefully. They knew that changes were always taking place in the earth and in the air around the earth. They knew that some days are cold, some are hot, some are rainy, and some are clear. And during the year the weather changes with the seasons. Men began to wonder what caused these changing *conditions* in weather and climate. They also wondered about the condition of the earth's surface.

FIG. 32. Wherever you are in the world, you will find domestic animals—horses and mules, dairy cows, beef cattle, sheep, hogs, poultry, goats, or dogs. For thousands of years animals have been helping man to do his work and providing him with food and clothing.

They wanted to know what made the mountains and the valleys and the plains. Why is the earth what it is, and why do conditions on earth change? This was a big and important problem for scientists to solve. It is an important problem for you to solve in your science study.

Scientists also became interested in the kinds of *materials* we find on earth. They tried to find out as much as they could about what things are made of and how they are put together. In our picture of the world we will want to learn more about the different kinds of materials and how scientists have learned to use them.

In our picture of the world we must not forget our *living neighbors*—the plants and the animals. They make an important part of our world. Without them we could not live. They have supplied materials for the clothes we wear, the food we eat, the paper we write on, the chairs we sit on, and the houses we live in.

As we look around us, we see moving things—moving windmills, moving trains, automobiles, and street-cars,

FIG. 33. Centuries ago men used the force of moving water to carry boats and rafts from one place to another. But it was only about seventy-five years ago that they learned how to use this force to run machines to make electricity, another great force. The force of the falling water at Niagara Falls makes electricity that moves street-cars and other machinery miles and miles away.

and moving water. All of these things are pushed or pulled by some *force*. Scientists have studied the forces of the world. They have learned how to use these various forces to move things that they want to move.

And last of all, no picture of the world would be complete if we did not look at ourselves. None of the discoveries about the world we live in could have been made by the plants and animals that surround us. Only *man*, of all the animals, has been able to understand the conditions, materials, living things, and forces that make up the world.

Now you see what you are to learn in this unit. You are to get a big picture of the world of conditions, materials, living things, and forces. Do not try to remember every fact. Try to see and remember what science is about.

FIG. 34. The earth is just one of thousands of millions of heavenly bodies that are scattered throughout the universe. This picture shows the heavenly bodies that can be seen through a telescope in just one tiny part of the sky.

Problem 1:

WHAT CONDITIONS SURROUND US ON EARTH?

WHAT KIND OF BODY IS THE EARTH? No matter where we are on earth, the sky is above us. In the sky we see the sun, the moon, and thousands of stars. Our nearest neighbor in the heavens is the moon, and it is nearly 250,000 miles away. Perhaps that does not seem near. But it is near when we compare it with the sun. The sun is over 90,000,000 miles away—nearly 400 times as far as the moon. Still farther out in space are several thousand million stars. Scientists call these vast spaces and all the heavenly bodies in them the *universe.*

Somewhere among these millions of heavenly bodies is a solid ball about 8000 miles in diameter. We call this ball the *earth.* It seems like a big world to us, but the sun would hold a million earths, and many of the stars are hundreds of times as large as the sun.

FIG. 35. This airplane picture shows just about all the kinds of earth surface there are—hills, valleys, level land, rivers, and ocean. Can you see in the picture any signs of how man has changed the earth's surface?

Even though the earth is only a flea among elephants, it is very important to us. This whirling, spinning ball of soil, rock, water, and air, lighted and warmed by the sun, is our home. From its mountains, plains, valleys, rivers, forests, oceans, air, and living things we get everything we need to keep alive and to make life comfortable and pleasant.

Let us look around on the earth to see what we can find out about our surroundings. First of all, we know that there are great differences in the surface of the earth. About three-fourths of the earth's surface is water in oceans, lakes, rivers, and brooks. Some parts of the earth are covered with large fields of ice. The solid parts are divided into mountains, hills, plains, valleys, and plateaus. Even the bottoms of the oceans are not all flat. They have great mountains, valleys, and

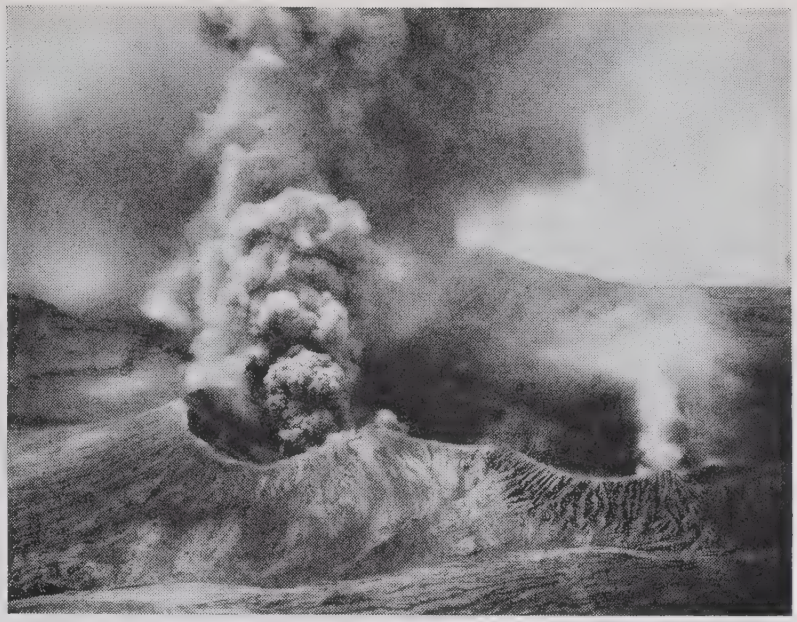


FIG. 36. Volcanoes have made great changes in the surface of the earth. In some parts of the world, there are active volcanoes like this one, that sometimes erupt and blow thousands of tons of melted rock into the air.

plains much like those we have on dry land. A little island is really the top of a mountain in the ocean.

As we walk on this solid earth or sail on the water, our bodies are bathed in an ocean of air. This air is as much a part of the earth as land or water. It surrounds the earth in a great layer. Nobody knows just how deep this ocean of air is, but it is probably more than 100 miles deep.

There is another important thing about the surface of the earth. It is always changing. Most of the big changes go on so slowly that you cannot see them. But scientists can measure them. For example, scientists have found that in southeastern England, as well as in other places, the land is slowly sinking. But the people there have no need to worry. It sinks only a few inches in a hundred years. The land in many other parts of the world is slowly rising.

We can see some of the changes in the earth's surface. A few years ago a volcano on an island blew up, and the

FIG. 37. Perhaps you live in a part of our country where terrible dust storms have taken place. If so, you know how wind can change the earth's surface. Every year wind changes the surface of the earth a little by carrying soil from one place to another.

island disappeared under the water. If you have ever stood on the bank of a great muddy river, you have seen thousands of tons of earth being carried by the water. Every day, all over the world, soil is being washed down into flowing streams and carried away to some other place. Winds are always blowing soil from one place to another. The terrible dust storms on the western plains of our country have moved thousands of tons of soil hundreds of miles. Yes, we live on a changing earth. We cannot stop most of the changes that take place, but we can learn why they happen. And sometimes we can tell when and where the changes are going to happen. Then we can protect ourselves against these changes, or we can use them in ways that are helpful to us.

HOW DOES THE SUN AFFECT THE EARTH? Every day a remarkable change takes place in the sky. Slowly the sun goes down, the light in the sky fades, and darkness comes upon us. Several hours later a dim light appears in the east and grows stronger and stronger. Finally the sun shows itself above the horizon. Darkness no longer surrounds us; day has come again. This great ball of light and heat that we call the sun is tremendously important to us in many ways.

As you probably know, the earth travels, or *revolves*, in a great pathway around the sun. It takes the earth one *year* to make the complete round-trip, and this round-trip is millions of miles long. To make this journey in one year, the earth travels at the terrific speed of over 66,000 miles per hour. You also know that the earth is constantly spinning, or *rotating*, like a top on its *axis*. It takes twenty-four hours, or one *day*, for the earth to turn itself around.

Do you see, now, what we mean by a day and a year? The way the earth moves around the sun gives us our days and our years.

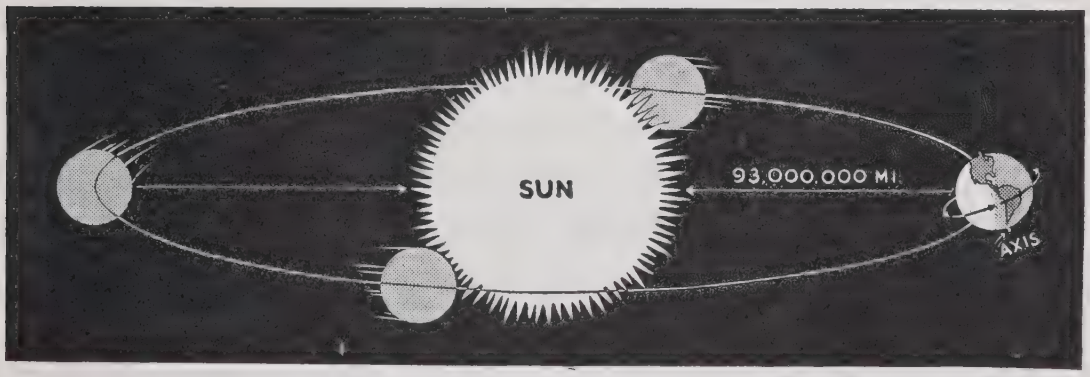


FIG. 38. The diagram shows how the earth spins around once each day on its axis and, at the same time, travels around the sun in a journey that takes one year to complete.

If the sun were closer or farther away, there would be a great change in the temperature of the earth. For example, Mercury, the planet nearest the sun, is believed to have a temperature of over 600 degrees. At this temperature lead will melt. Pluto, the planet farthest away from the sun, has a temperature hundreds of degrees below zero. On the earth the temperature ranges from sixty degrees below zero in the coldest regions to 120 degrees above zero in the hottest regions. This condition of temperature is very important to all living things. It determines what kinds of living things can exist in the different parts of the world.

Have you ever stopped to think what the earth would be like if it kept the same side toward the sun and if it did not move around the sun? Under these conditions, the part facing the sun would have no night, and the opposite side of the earth would have no day. The temperature on the side facing the sun would always be very hot, since it would be receiving heat from the sun all of the time. On the opposite side of the earth the temperature would always be very cold. Probably all plants and animals would die on that cold side of the earth.

WHAT ARE THE CONDITIONS OF WEATHER AND CLIMATE? Of all the changes in the conditions that surround us on earth we probably notice most quickly the changes in the weather. Sometimes the air is cold; at other times it is hot. At night the temperature usually falls, and in the daytime it usually rises. When you look at the sky, sometimes you find it blue and at other times cloudy. Every once in a while water in the form of rain, snow, or hail falls on the earth. At other times the air dries up

FIG. 39. Our food, clothing, and shelter, and many of the things we do depend on the kind of climate in which we live. Amid the snow and ice of the polar regions this man lives quite differently from the Africans in Figure 40.

water from the earth, plants wither and die, and dust flies with every breeze. Occasionally violent windstorms sweep over various parts of the country, doing great damage. These changes that take place from day to day we speak of as changes in *weather*.

When we talk about the temperature and the rainfall in any part of the world, we use the word *climate*. Thus a region has a hot, dry climate, or a hot, wet climate or a dry, cold climate, etc. You know that there are great differences in climates in different parts of the earth. Near the poles it is always very cold. Near the equator it is hot all the year round. Temperature, of course, is only one part of climate. The amount of rainfall is another part.

Climate is very important to every living thing on earth. As you know, the plants and animals of the desert are very different from those found in regions of heavy rainfall. The climate of a region almost tells

FIG. 40. A village in the hot, rainy forests of Africa.

us the kinds of plants and animals that can live there. It also determines many things about the ways in which men and women live. The clothes we wear, the kinds of houses we build, some of the foods we eat, and even some kinds of play depend upon the climate of the place in which we live.

And now we have explored in a general way the conditions that surround us on earth. We cannot change these conditions. We cannot move the earth closer to, or farther away, from the sun. We cannot stop it from spinning on its axis or from revolving around the sun. We cannot do anything to regulate the weather or to change the climate. As someone once said jokingly, "Everybody complains about the weather, but nobody does anything about it." We cannot stop the big changes in the surface of the earth.

We live the way we do because of the conditions that surround us on the earth. We sometimes read that man

has conquered nature. Nothing could be farther from the truth. We cannot conquer nature or change it. We study science so that we can understand our world better. The better we understand our world, the better we can fit ourselves into the conditions that surround us in our world.

Self-Testing Exercises

1. Without using your book, write an answer to the problem, "What kind of body is the earth?" Answer in about one-half page by telling only the more important things.
2. How would the conditions on the earth be different if the earth (*a*) did not revolve? (*b*) did not rotate? (*c*) were as far away from the sun as Pluto? (*d*) were as close to the sun as Mercury?
3. List three important ways in which the weather changes where you live.
4. List two important ways your life would be different if you lived in a very hot climate (Figure 40) and two ways it would be different if you lived in a very cold climate (Figure 39).
5. What are some of the ways in which men have made themselves more comfortable against the conditions on your part of the earth?

Problem 2:
WHAT MATERIALS DO WE FIND IN OUR WORLD?

WHAT ARE SOME OF THE NATURAL MATERIALS WE USE? Fortunately for us, this world we live in gives us countless materials for making things. You are surrounded with them as you read this book. Every day you use iron, wood, rubber, wool, sugar, lead, water, cotton, glass, and many other things. The world is a rich storehouse of materials. Scientists have discovered many of these materials for us and have shown us how to use them.

FIG. 41. In some of the great museums you will find scenes like this. They show what scientists have learned about how people lived on earth hundreds of thousands of years ago. This picture shows two cavemen making crude tools and weapons. They used only the natural materials around them. Stones were hammers to chip off other stones for knives and ax heads. Branches made the handles for stone clubs and axes. (Field Museum.)

How long do you suppose it would take you to make a list of all the different materials that scientists have discovered and named? If you wrote at the rate of ten materials a minute for eight hours a day, it would take you about two months to finish the job. There are over 300,000 materials that differ from each other in one or more ways. Most of them you have never even heard of. Perhaps you wonder where all these materials come from. They all come from this earth on which we live. Some of the materials we use just as they are found in nature. We call these *raw materials* or *natural materials*. Others we make by mixing raw materials together or by taking them apart.

When men first appeared on earth, the earth was full of all the natural materials that are in it and on it today. If men had known how to discover and use them, they could have had everything that we have. But they did not know how. Of all the thousands of materials that

FIG. 42. One of the largest iron mines in the world is north of Duluth, Minnesota. Here the iron ore, looking like red dirt, lies near the surface of the ground and is scooped up by large steam-shovels.

nature provided them, they used only a few. The other materials lay in and on the earth waiting for the time when men should learn how to discover and use them.

For thousands of years the discoveries that man made about the materials of the earth were accidental. Men learned what they could by "hit-or-miss" methods. For example, one kind of iron, as it is found in the earth, looks like red dirt. No one would guess that it contained iron. Perhaps someone built a fire on this kind of red earth and in stirring through the ashes discovered some strange-looking lumps. This probably happened many times before some man was smart enough to discover that these lumps could be pounded into different shapes to make tools and weapons. But, as you found in Unit One, men finally learned how to study the earth scientifically.

LIBRARY OF THE UNIVERSITY OF ALBERTA

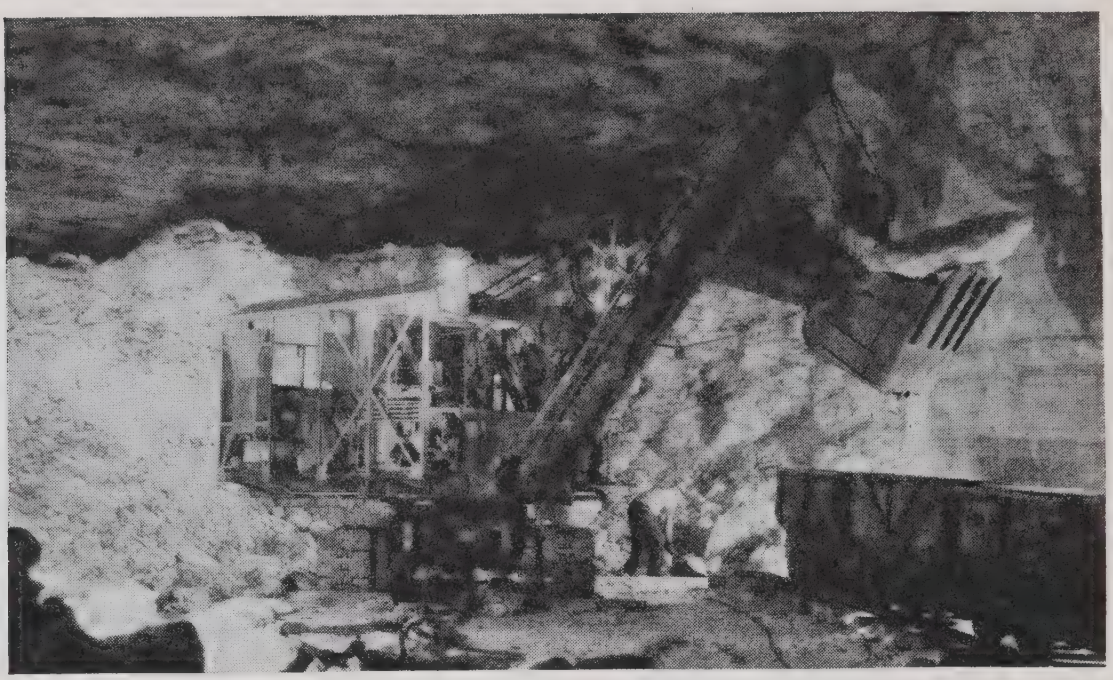


FIG. 43. Some of the salt mines in our country are so large that great mechanical shovels are used to load cars with the heavy chunks of salt.

And now let us think about a few of the most important sources and kinds of materials that man uses. The surface of the earth provides us with soil in which to grow our plants. It also supplies us with clay, sand, and rocks for building materials. Under the surface of the ground we find the *ores* of metals, that is, the rock, sand, or dirt mixed with metals such as lead, iron, tin, copper, nickel, gold, platinum. We also find in the earth such materials as salt, sulphur, borax, and numerous others. These supply the materials necessary to manufacture baking soda, matches, fertilizers, and other substances used in the home, on the farm, and in industry.

And we must not forget coal, oil, and natural gas. These supply us with fuel to keep our buildings warm and to run our machines.

Then, of course, we get many different materials from our living neighbors. Plants provide us with fruit, vegetables, nuts, and seeds for food, fibers for cotton and linen cloth, and medicines, wood, cork. Animals provide us with food, wool, leather, glue, and many other materials.

HOW DO SCIENTISTS WORK WITH MATERIALS? There are four important things that the scientist does with materials: (1) He discovers new materials. (2) He studies the materials to find out what they are made of. (3) He finds how to take materials apart so that he can get two or three or more materials from one kind of material. (4) He experiments with putting materials together to make new and different materials. Now let us see just what we mean by these four things that the scientist does.

For hundreds and hundreds of years mothers probably scolded their children for getting dirty with a certain kind of sticky brown clay. Undoubtedly the children had great fun making mud pies, balls, and perhaps even dishes from this clay. As the mothers washed the dirty hands and faces of the children, they never dreamed that some day other mothers would be cooking food in pots and pans made from a valuable material in that clay. The material was *aluminum*. There were tons and tons of it in the clay. But no one had ever heard of aluminum. No one knew that there was aluminum in the clay. It was only about a hundred years ago that scientists discovered the material and worked out a way of getting it from the clay.

Let us take another example. For hundreds of years men and women burned coal for heat. To these men

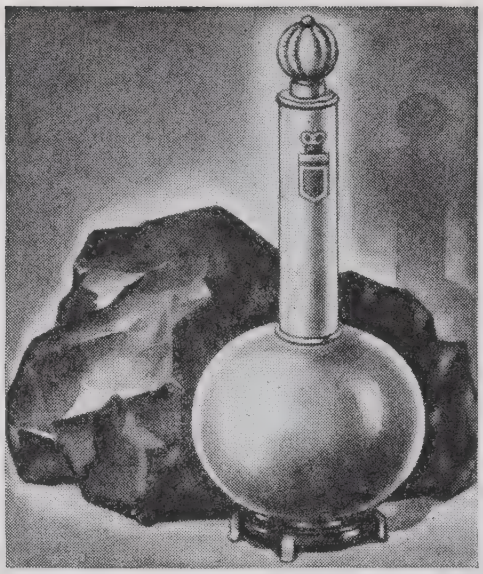


FIG. 44. From black lumps of coal come the materials for perfume.

and women a lump of coal was only a black stone that made hotter and better fire than wood. Then men began to learn how to be scientists—to think, study, and experiment the way scientists do. They went to work studying this black stone. They crushed it, heated it, and did all sorts of things to it to find out what it was made of. And what do you suppose was the result of all this thinking and experimenting? They found that this black rock-like stuff was made of many different materials—materials that they could use in hundreds of different ways.

Believe it or not, from black coal there are made over one thousand different dyes for coloring. The red color in the "hot dog" you eat and the yellow of the butter probably were made from materials found in coal. The soda pop you drink is colored with dyes made from materials in coal. When the dentist puts something into your jaw to keep your tooth from hurting while he drills it, he is using a substance made from coal. Even perfumes are made from materials found in coal!

For hundreds of years all vanilla flavoring came from the bean of the vanilla plant. But now scientists have learned how to make it from coal. And just as this book was being written, scientists discovered that vanilla flavoring could be made from certain substances found in wood.

FIG. 45. This Bedouin family has made a house of simple materials—reed matting laid over poles stuck in the ground. The Bedouin family would gaze with wonder at the home shown in Figure 46.

Your own home is a good example of what scientists do with materials. Just imagine what a cave-man would think if he could see a modern home. He would be amazed at the smooth, nicely shaped stone that makes the foundation. He would wonder how men ever cut and handled such an enormous rock. You would have to tell him that men took some materials from the earth, mixed them together, heated them, and made cement. Then they mixed the cement with gravel and small stones, added water, and made concrete. The concrete hardened into a single piece of artificial stone.

The cave-man would never be able to understand window glass. But you would tell him that it was nothing but sand and other materials mixed together and allowed to cool and harden. He would think he recognized some leather, perhaps, on a chair or a book cover. But you would tell him that it never came from the skin of an animal. It was artificial leather. Your cave-man would find it hard to understand all these strange materials.

FIG. 46. How many of the materials used in this room can you name? Where did they come from?

We could go on for pages and pages telling of the wonderful discoveries scientists have made and are making with the materials of this world. Paint, varnish, paper, Bakelite, linoleum, cloth made from wood, and steel that will not rust are only a few samples. As you study science, you will learn of many more materials, and you will find out how they are made. Men and women who spend their lives studying what materials are made of, how materials can be taken apart, and how they can be put together are called *chemists*. *Chemistry* is the science or knowledge of how the materials of the world are made.

Self-Testing Exercises

1. What four things do scientists do with materials?

2. Why do we have more materials today than men had five or ten thousand years ago?

3. Make a table like the one on page 57. Draw the lines with a ruler. In each column write as many materials as you can. Write an N after each material that is used as it is

found in the earth, for example, limestone. Write an M after each manufactured material, for example, brass.

After you have thought of as many materials as you can, look through the pages you have just read to find the names of other materials. Add them to the list.

Classification of Materials

Building Materials	Fuels	Clothing Materials	Chemicals	Miscellaneous

4. Write a sentence or two that will define or explain each of these words or phrases: *chemistry, natural materials.*

Problem 3:

WHAT LIVING NEIGHBORS DO WE HAVE?

So far you have learned something of the conditions and the materials of the world we live in. But conditions and materials are not all that make our world the kind of world it is. Let us get a big picture of another part of our surroundings. We live in a world of living things—plants and animals.

If you were asked to guess how many different kinds of animals there are, what would you say? Probably you have seen only a few hundred kinds. Scientists, however, have found and named over 800,000 different kinds of animals. Each of these kinds of animals differs in some ways from all other kinds. You would probably be far wrong in your guess as to the number of different kinds of plants. At the present time over 225,000 different kinds of plants have been discovered and named.

FIG. 48. From left to right, beginning at the top and going around the border, the animals are: jellyfish, Ichneumon fly, centipede, butterfly and snail, praying mantis, tree frog, sea-cucumber, and woodpecker.

WHAT ARE SOME OF OUR ANIMAL NEIGHBORS? First, let us look more carefully at our animal neighbors. Some of them are so very small that they can be seen only with a powerful microscope. Figure 48 shows one of these tiny creatures, an *amoeba*. It is difficult to believe that it is an animal. It does not look like any of the animals you know. It has no eyes, ears, legs, nose, or even any part that looks like a head. It is only about one one-hundredth of an inch across. If you study an amoeba under the microscope, you will find, however, that it moves and eats food.

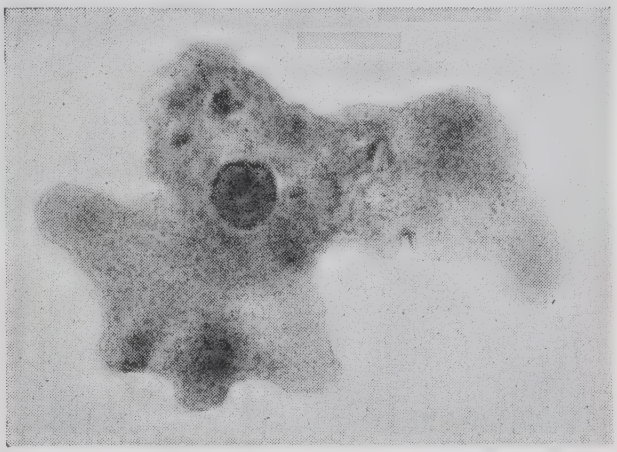


FIG. 48. An amoeba

The largest living animal is the whale. Whales have been captured that weighed seventy tons and were over 100 feet long. It would take 1000 men weighing 140 pounds each to equal the weight of one such whale. In between the whale and the amoeba are animals of many different sizes.

The differences in shapes of animals are probably even more striking than the differences in sizes of animals. For example, think of the elephant, the crayfish, the lion, the monkey, the snake, the giraffe, the oyster, and the earthworm. Look at the pictures of queer animals in Figure 47 to see still other shapes. It does not seem possible that animals could be of so many different shapes and still be animals. Scientists have been trying to explain this for a long time. Later in your study of science

FIG. 49. In the midst of a group of "big trees" in Sequoia National Park, California, people become dwarfs. Some of these trees were already old when Columbus discovered America.

you will learn how scientists explain all these different kinds of animals.

There are many other interesting things to learn about our animal neighbors. Some of them live only on land, some live only in water, and others live both on land and in water. Some animals eat only animals, others eat only plants, and some eat both plants and animals. If you live in New England and go to Florida or to Texas or to Oregon, you will find many kinds of animals that you have never seen in New England. Some kinds of animals can live only in hot regions, while others can live only in cold regions. These are just a few of the things that we can learn from a study of the science of living things.

WHAT ARE SOME OF OUR PLANT NEIGHBORS? And now let us think of our other living neighbors—the plants. There is an even greater difference in size between the smallest plants and the largest plants than

between the smallest and largest animals. The smallest plants are the *bacteria*. Bacteria are so small that it would require about 1500 of them to cover the top of a pinhead. It is no wonder that bacteria were not discovered until the microscope was invented. You have probably never seen any of these tiny plants, but they are on you, in you, and all around you. They are very important to you. Some of them make you ill. Others help you in many ways. As you read these pages, hundreds of scientists all over the world are studying how to protect men and women against harmful bacteria and how to use the helpful kinds.

FIG. 50. A wood fungus has no leaves, stems, roots, flowers, or seeds; but it is a plant.

The largest plant in our country is a tree known as the sequoia, a big tree of California. It grows over 300 feet into the air, and may be thirty feet thick at its base. In between the bacteria and the sequoia are plants of many different sizes.

You have seen plants such as trees, shrubs, grasses, and vines. All of these plants have leaves, stems, and roots, and at some time during the year they may also have flowers and seeds. But not all kinds of plants have roots, stems, leaves, flowers, and seeds. Probably you have seen a green stain that grows on the bark of trees. Scrape off a little of this green material, place it on a piece of glass, add a drop of water, and look at it through a compound microscope. You will

Fig. 51. It took fifty years for Luther Burbank, a famous American experimenter, to find out how to grow the Elephant Heart plum, which is almost the size of an apple. Notice how much larger it is than the Green Gage plum shown at the left. Scientists have found how to grow many new food plants.

see that it is made up of many tiny plants without leaves, stems, roots, flowers, or seeds. Mushrooms and molds are other plants that do not have leaves, flowers, or seeds. You can easily see that plants are like animals. Some plants and animals are very simple in *structure;* that is, they have only a few parts. Others are very complex; they have many different parts.

WHAT DOES MAN DO WITH HIS LIVING NEIGHBORS? Very early in his life on this earth man probably thought of all living things as either friends or enemies. Animals and plants that did not harm him and that furnished him with food or clothing were his friends. Animals that tried to kill or injure him were enemies. Plants that made him sick or tore his skin with thorns were enemies, too. Of course, man tried to preserve his friends and destroy his enemies among living things. He had to do this, because the friendly living things provided him with all his food and his clothing.

But man was not satisfied with the plants and animals that he found in nature. He began to try to improve the ones that were useful to him. Scientists have done just

FIG. 52. Man has learned many ways of protecting his food plants from disease and insects. In this picture fruit trees are being sprayed with poison to kill insects.

as wonderful things with plants and animals as they have with coal and other materials. Wild plums are not much bigger than marbles. But the scientist learned how to make them grow into the large juicy plums we now have. Wild horses were little fellows that you would call ponies. From these small wild horses man has developed the beautiful, powerful horses that haul great loads and do other work for us. Grapefruit never grew wild in nature. But from plants that nature did provide, man learned how to grow a grapefruit plant. One famous experimenter even grew a plant that produced white blackberries.

Scientists had to make many discoveries and solve many problems before they could improve plants and animals. They had to learn how living things grow,

what kinds of food are best for them, and how much light and heat and moisture plants need. Plants and animals get sick; so scientists have studied the diseases of plants and animals and have learned how to cure many of them.

Throughout the world today thousands of scientists are every day studying our living neighbors, finding how to use and improve the helpful ones and how to destroy the harmful ones. The scientists who study living things are called *biologists*. *Biology* is the science or knowledge of living things. Every year biologists are finding ways of growing more useful plants and animals. But there are still plenty of problems for the biologists to solve. Perhaps some day you will be helping to solve these problems.

Self-Testing Exercises

1. List ten kinds of plants and ten kinds of animals found near your home. From all the lists in the class make a big list of plants and a big list of animals. Label it "Our Living Neighbors."
2. State five problems that men had to solve before they could improve plants. Your first problem might be, "How do plants grow?"
3. List five ways man has made living things better for his needs.
4. Define the word *biologist*.
5. What are bacteria?
6. Give three ways in which a mushroom is different from a dandelion.
7. Is a butterfly an animal?
8. Make a list of five ways in which animals can be different from each other.

Problem 4:

WHAT NATURAL FORCES DO WE USE?

In the first three problems of this unit you have learned many things to help you understand what kind of world you live in. You have been reading about the conditions, the materials, and the living things that surround you.

There is another very important thing to study in our surroundings. We live in a world of moving things—moving air, water, automobiles, trains, airplanes. We ourselves, or parts of us, are always moving. But nothing in this world moves unless it is pulled or pushed by some kind of force. We live in a world of forces. You can quickly realize how important they are if you try to imagine a world in which nothing moves. Let us learn first about the greatest force of all.

Fig. 53. The force of gravity is bringing the parachute jumpers back to earth again.

Everything is held to this whirling, spinning earth by a mysterious force called *gravity*. No one knows just what gravity is. But you know that if you step out of an airplane in mid-air, you will fall to the earth. The force of gravity keeps you from falling off the earth as it whirls around through space. It is the force of gravity that brings a baseball down when the ball is thrown

FIG. 54. On the Nile River for thousands of years men have used the force of wind to push boats through the water or have floated along with the current.

into the air. "All that goes up must come down on somebody's head or crown" is not a joke. Airplanes may rise against the force of gravity if their engines produce enough force, but if the propeller stops turning, down they will come. There is no getting away from the force of gravity. We may not know what gravity is, but scientists have discovered some amazing things about how it works.

You have seen another effect of the pull of gravity when you have watched a moving stream. What do you suppose makes the water flow in the direction it does? Water is a liquid and is free to move in any direction, as you have discovered when you spilled a glass of water on the table. Gravity pulls on it, just as it does on everything else. Since water is free to move, it flows from higher places to lower places. Primitive man used the force of gravity when he traveled downstream on a floating log. Since those days scientists have shown us how we can use the force of moving water to work for us.

On your way to and from school you may have had an unpleasant experience with gravity. A sudden gust

of wind may have blown off your hat and sent it sailing down the street. Perhaps you wonder why we blame gravity for this happening. That is one of the important things you will learn in your study of science. Men probably first used the force of wind to push a sail-boat through the water. Someone finally invented the windmill; exactly when, no one knows. We do know that they were used in Europe 700 years ago.

There are, however, other powerful forces in the world. One of these is steam. Steam was known as far back as 2000 years ago. A Greek by the name of Hero developed an engine that was driven by steam, but no practical use was ever made of it. Seventeen hundred years later, however, men in England were at their wits' end to keep water out of a coal mine. They could not work the pumps fast enough. Even the horses that they sometimes used for power could not make the pumps work fast enough.

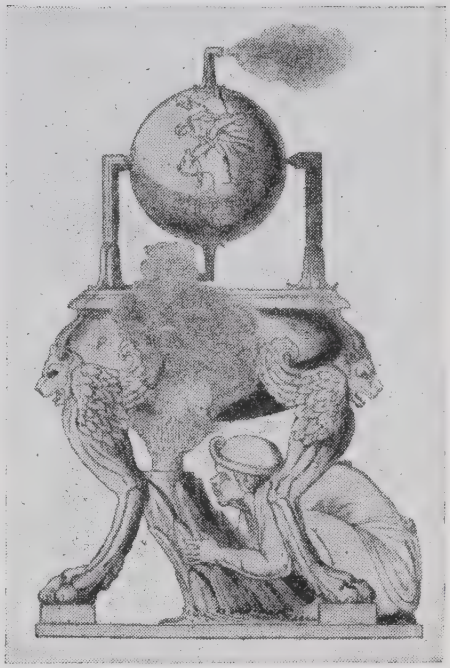


FIG. 55. Hero's steam engine was not at all like a modern steam engine. Water was heated in the bowl. Steam entered the ball at the sides. As steam escaped through the two nozzles, it forced the ball to spin around.

Here was a job in which the ordinary sources of power would not do. So men experimented with steam, and they invented an engine that used the force of steam to make it run. These steam engines worked the pumps fast enough to keep the water out of the mines. Since

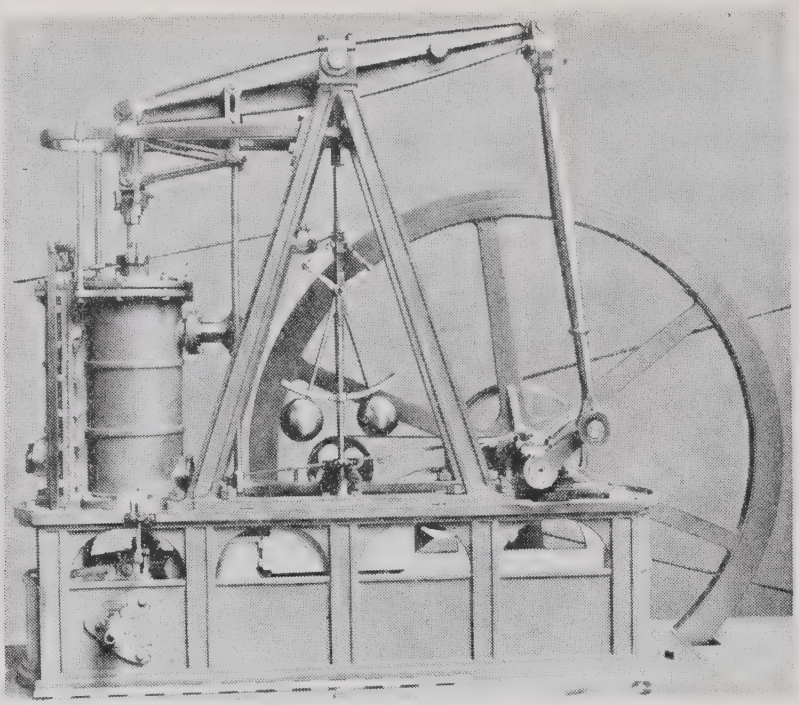


FIG. 56. About 150 years ago James Watt, a Scottish inventor, developed a steam engine that could do more than run pumps; it was powerful enough to run machinery of all kinds. This picture shows that first real steam engine.

those days scientists have made the steam engine even more powerful than it was at first.

For a long time the steam engine supplied most of the power in places where there was no moving water for power. But men were experimenting with electricity. From the beginning of time there had been electricity in nature ready for man to use. Man saw it in the lightning. But he did not know how to make it useful. About 150 years ago Alessandro Volta, an Italian scientist, invented the electric cell. This, however, would not produce electricity in large quantities. But it started scientists to thinking about and experimenting with electricity. After about fifty years scientists invented a machine that could make large quantities of electricity. Today electricity runs street-cars, helps make automobiles move, lights our homes, cooks our food, and does many other things for us.

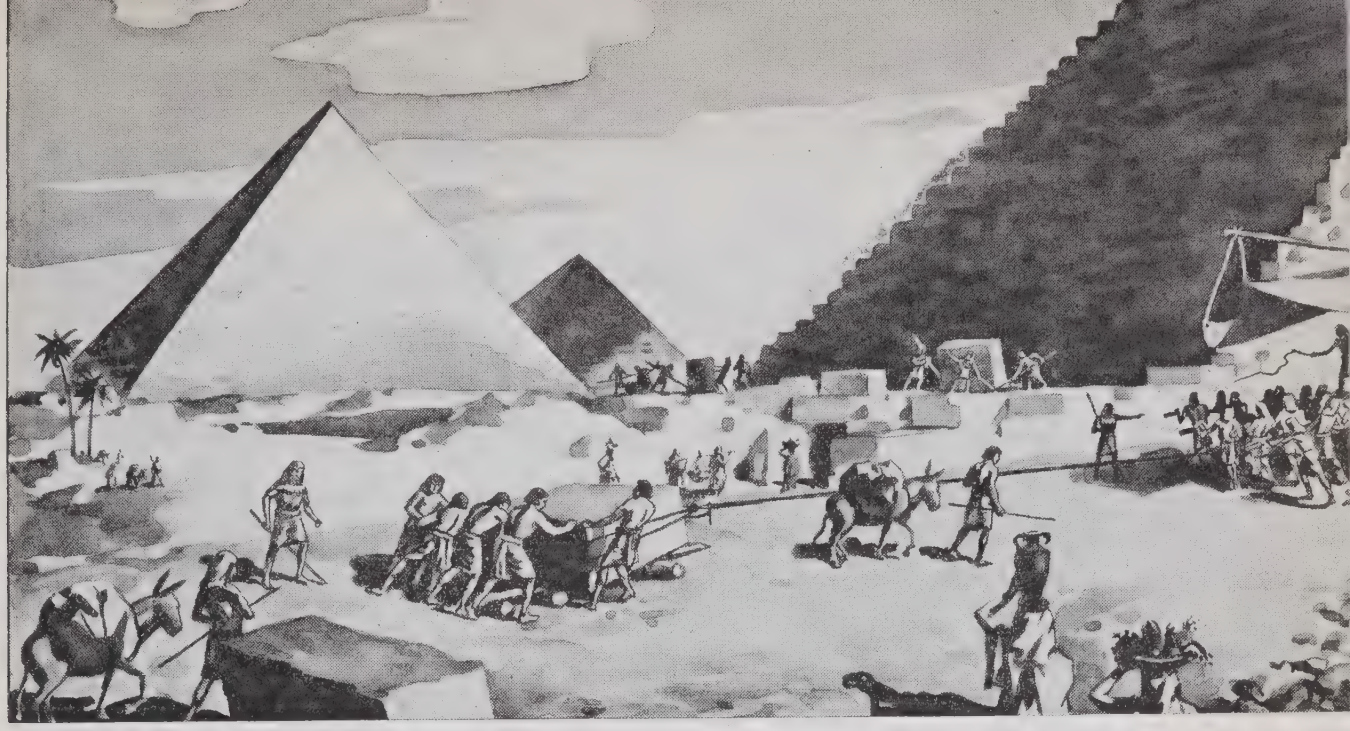


FIG. 57. When men built the pyramids of Egypt thousands of years ago, they had only the force of their own muscles and of the muscles of donkeys to do the work. One historian says that it took 100,000 men twenty years to build the Great Pyramid. This pyramid contained over 2,000,000 blocks of stone, weighing altogether over 6,000,000 tons. All this stone was cut, hauled, and lifted by the strength of men and animals.

About fifty or sixty years ago inventors gave the world another important power machine. This was the gasoline engine. Man had learned how to make gasoline from the oil he found in the earth. Then he had learned that gasoline could be made to change into a gas that would explode with terrific force. The next thing was to invent an engine that could use the force of the exploding gas. You know that men did invent such an engine. We use this engine to run our automobiles, our airplanes, and many other kinds of machines.

Now you have learned the most important forces that man uses to do his work. There are other forces about which you will learn, but these are the important ones. So long as men had to do all of their work with their own strength, they could make little progress.

There was more work to be done than they could do. But the forces of nature have multiplied man's own force. Scientists have discovered and harnessed these forces of nature for us. Because they have done so, we live very differently from the people of even 100 years ago.

FIG. 58. A pile-driver

Self-Testing Exercises

1. Write a story telling what the world would be like if all forces stopped.
2. What three forces did man use thousands of years ago?
3. What three forces had to be discovered by scientists?
4. What force makes rivers run to the ocean? Give two ways you use that same force.
5. One of the machines in common use is the pile-driver. A heavy weight is lifted and then let fall upon a pole that is to be driven into the ground. What force is being used?
6. Make a table like the one below. In each column name machines that you have seen operated by the power machine named at the top of the column, as shown under "Water-wheel."

KINDS OF MACHINES

WATER-WHEEL	WINDMILL	STEAM ENGINE	ELECTRIC MOTOR	GASOLINE ENGINE
Dynamo				
Sawmill				

Problem 5:

WHAT KIND OF BODY DOES MAN HAVE?

WHAT CAN OUR BODIES DO? You have been reading about the kind of world you live in. You have also seen what wonderful things man has been able to do with the materials, the conditions, the forces, and the living things of the world. Why has man been able to do all these things? You are just as much a part of nature as the rocks, the trees, the animals, the winds, and the soil. But you are superior to them all. You can do things that no other living thing can do. Let us see if we can find what it is that makes man superior to every other thing in nature.

It is seven o'clock in the morning. The alarm clock rings, and you wake up to see the morning sunlight streaming into your window. You jump out of bed, perhaps stub your toe on a chair, take a cold bath that sends shivers up and down your spine, get dressed, and hurry down to get your breakfast. Do you realize what a complicated machine it takes to do all of the things that you have done? Think for a moment about the things you were able to do.

First of all, you heard the alarm clock (at least we hope you did). It was on the table several feet from you. You were able to hear it because you have an ear that can catch sound. You saw the sunlight because you have eyes with which you can see. You felt the chair against your toe and the cold water on your body because tiny *sense organs* in the skin sent messages to your brain. You enjoyed your breakfast because you liked the smell and the taste of the food. Your nose and tongue helped you enjoy the food. These sense

FIG. 59. Here you see people engaged in different activities: skiing, playing musical instruments, operating a telephone switchboard, and bicycling. They can do all these, and many other, things because they have brains, skilful hands, and sense organs.

organs (eyes, ears, nose, tongue, etc.) let you know what is going on in the world. They tell you what is happening to your own body, and they tell you of many things that are happening at a distance from you.

WHY IS MAN'S BODY SUPERIOR? Other animals have sense organs; some of them have even better sense organs than you have. A dog, for example, recognizes people by his sense of smell. He can even track people by the sense of smell. You cannot do this, but

you can do many things that the dog cannot do. Look at your fingers. No other animal has fingers that can do what man's fingers can do. Even if a dog knew all about building houses and the use of electricity, he could not use his knowledge. He has no fingers with which to make things.

Along with these useful fingers man has a brain that tells his fingers what to do. No other animal could invent a typewriter or a vacuum-cleaner. The other animals do not have brains that can think and plan and study. You have seen animals do tricks, but they did not think out a way of doing the tricks. Men taught them how to do tricks. Beavers build the same kinds of homes they built a thousand years ago. They cannot study and plan how to make better homes.

Furthermore, only man can write down his ideas for others to read. With his brain and his fingers he has developed a written and spoken language, printing-presses, photography, the phonograph, the radio, and the motion picture. Thus a man or woman in one part of the world can know what someone in a far distant part of the world has thought, discovered, or invented.

Then, too, because man can make a record of what he thinks and does, generations of people who live after him can know what he has learned and done. We, today, know what man learned thousands of years ago. We profit from these discoveries and inventions. When an animal dies, everything that it knows dies with it. A wily old grizzly bear may have learned how to escape death by dodging hunters, but he cannot pass this knowledge on to younger bears so that they may profit by his experiences. Of course, bear cubs learn some

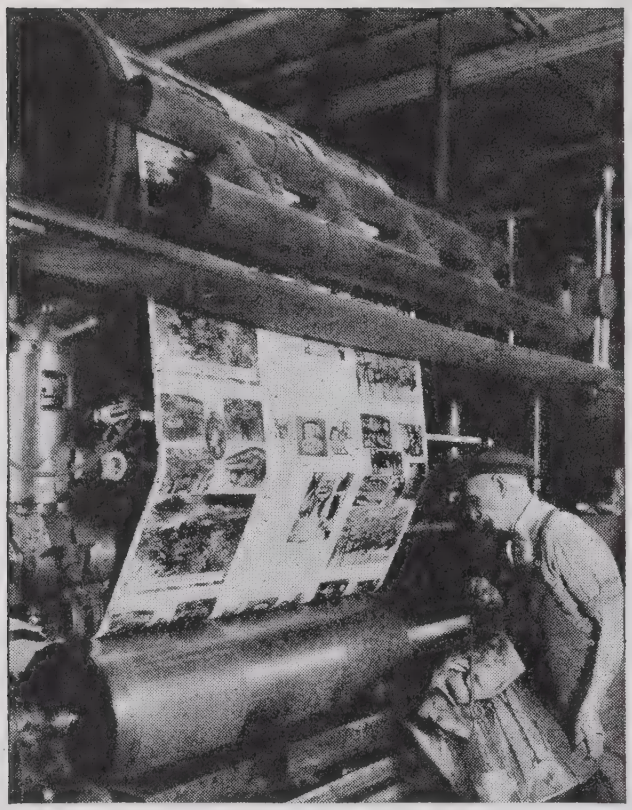


FIG. 60. You all enjoy the picture section of a newspaper, which is being printed here at high speed by an electric-driven press. But neither the newspaper nor the complicated machine would be possible without man's brain and fingers to plan and make them and his brain to understand the printed words.

things by imitation, but the old bear cannot write a book on "How I Escape Capture and Death" so that other bears may learn from his written words.

With a brain to remember, make plans, and solve problems, and nimble fingers to make things, man has been able to use this world in ways that no other living thing can use it. He has been able to do many things to keep himself alive that no other living thing can do. With his bare hands he cannot kill a dangerous lion or tiger. But with his thinking brain and his skilful fingers he can make clubs, spears, bows and arrows, and guns with which to protect himself. He cannot live naked and exposed during the long bitter cold of winter. But his brain and his hands make it possible for him to build snug shelters, make warm clothes, and use fire for warmth.

And perhaps you have never thought of another very important thing that man's brain has done for him. It

has helped him not to be afraid. People are afraid of things they do not understand. Thunder and lightning are terrifying, mysterious things to the ignorant savage. Even the whispering of the wind through the trees makes him imagine that evil spirits are there. A volcano is an awful god to whom offerings must be made every year. The steam locomotive and the automobile frighten savages when they first see them. Ignorant people are afraid of something most of the time, because they do not understand what kind of world they live in.

But with all the inventions and discoveries man has made, he has never conquered nature. He must obey the rules, or laws, of nature. You can quickly see that man cannot do exactly as he pleases. Think of the care you must take of your body if you wish it to work well.

For example, you may decide that sleeping is a waste of time. You may decide this, but nature has decided differently. After a time you will fall asleep no matter how hard you

FIG. 61. Dogs do not think of tricks to do, but they may be taught how to do tricks. After dogs have once learned tricks, they cannot teach other animals how to do them.

try to stay awake. You may like candy so well that you decide to eat only candy for your meals. You know what will happen. To keep well there are many things that you must do in the right way.

And now you have a picture of the world you live in. Certain conditions, materials, living things, and forces make it the kind of a world that it is. In some ways man can change this world. He learns all that he can about the world. He then uses this knowledge to help fit himself to his surroundings.

Self-Testing Exercises

1. Make a list of things that your body can do.
2. Give the two most important ways in which your body is better than that of a dog.
3. In what ways are the bodies of animals better than yours.
4. How does a good brain make up for the things you listed in your answer to No. 3?
5. What are some of the things that man has learned to do in order to keep his health?

LOOKING BACK AT UNIT TWO—SUMMARY EXERCISE

See how many of the important ideas in Unit Two you can show in a kind of diagram or cartoon. Use a full-sized sheet of paper. Begin by drawing a six-inch circle on the lower two-thirds of the sheet. Show the sunlight coming down on the earth, and label it. Make arrows to show the two motions of the earth and write the name of each motion beside its arrow.

Show some of the mountains and other features of the earth's surface, the living inhabitants, the conditions that surround them, and the forces that they feel and use. Do as much as you can without looking at the book. Then turn through the book and put in any important things you did not think of.

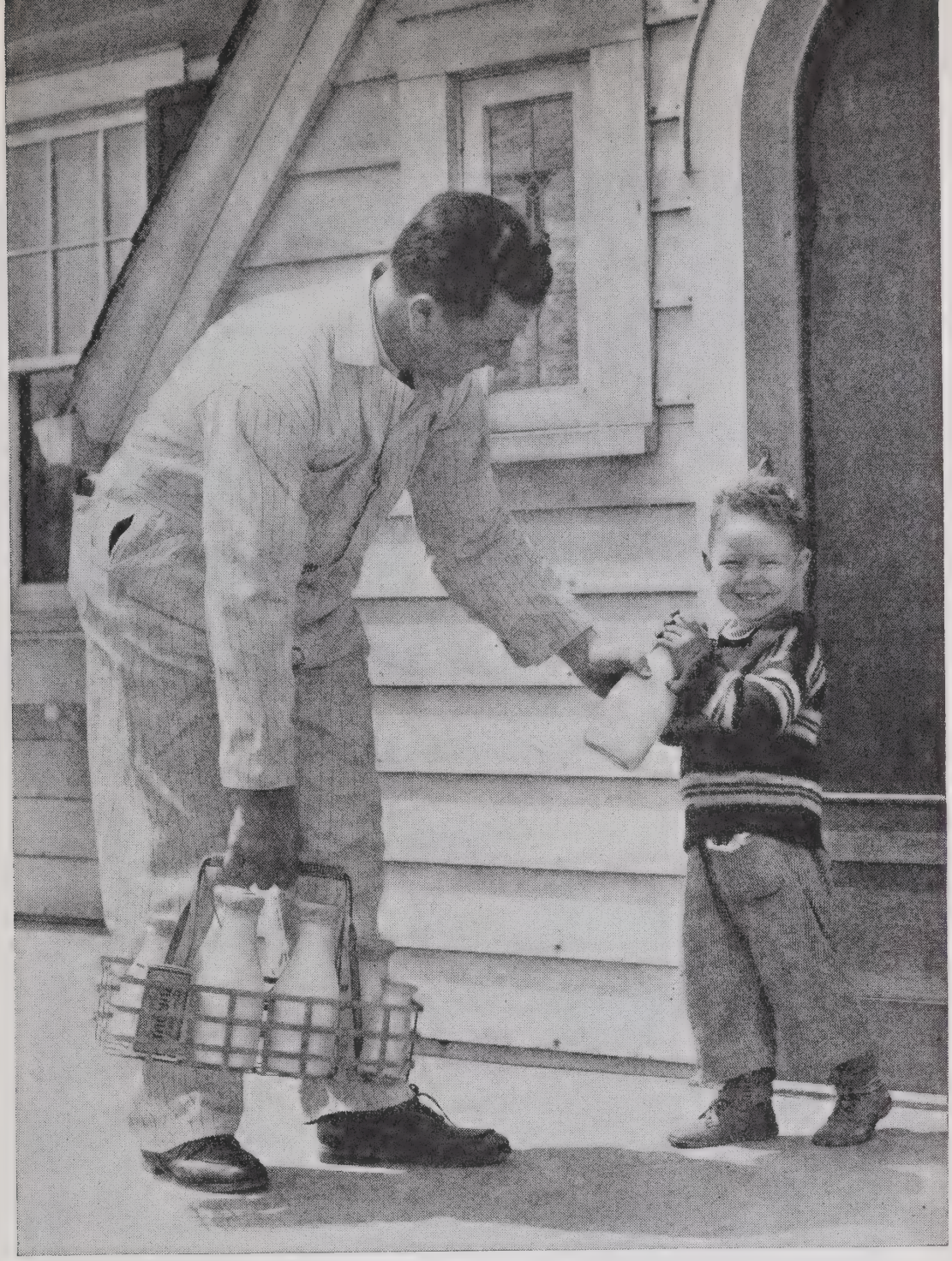


FIG. 62. Do you know how the house, the little boy, the milkman, the milk, the bottles, and even the wire screen in the door are all alike? This unit will tell you many interesting things about materials.

UNIT THREE

UNIT 3

WHAT IS A MATERIAL?

INTRODUCTORY EXERCISES

1. In what ways are a book and an ink bottle different from each other?
2. In what ways do you think a book and an ink bottle are alike?
3. In what way is a liquid such as water different from a solid such as wood?
4. In what two ways are water and wood alike?
5. Wood, glass, and water are materials. Is air a material, too? State reasons for your answer.
6. What do you mean when you say that something has dissolved?
7. Does a flat automobile tire weigh more or less than the same tire when it is pumped up hard? Why?

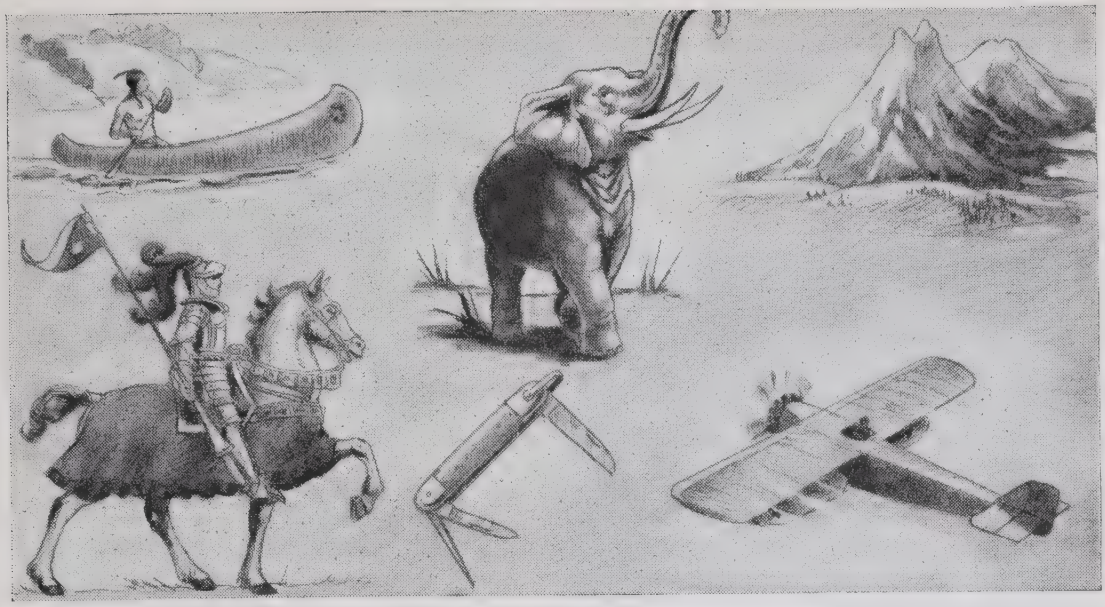


FIG. 63. The things in this picture look quite different to you. But they are all alike in some ways. Do you know what these ways are?

LOOKING AHEAD TO UNIT THREE

THE introductory exercises have probably made you wonder what this unit is about. Perhaps some of the questions even seemed foolish to you. "Everybody knows," you may have said to yourself, "that a book and an ink bottle are not at all alike. One is made of paper and cloth, and the other is made of glass. They are not even used for the same purpose." Perhaps it seemed still more foolish to you to think that water and wood are alike. So you are probably wondering why you are asked all these questions that cannot be answered.

But, strange as it may seem, an ink bottle, a book, wood, and water are alike in some ways. We can go even farther and say that air, too, is like wood and water. Perhaps you cannot see why this is true. But you will see how they are alike when you have studied this unit.

When you have found out how materials like air, wood, and water are alike, you will not make the mistake that John did one day. The teacher placed three drinking glasses on the table. She poured water into one glass and put soil in another. She put nothing in the third glass. Then she asked John to look closely at the glasses to see if each glass was full of something.

FIG. 64. Do you think that one of these glasses is empty?

John was so sure of himself that he quickly said, "One is full of water, one is full of soil, but the third one is empty." Nearly everyone in the class thought that John was right. Perhaps you think so, too. But Henry did not think so. He said, "Each glass is full of something." John argued with him, but Henry stuck to what he believed. "I can prove it," he said. How do you suppose Henry proved that none of the glasses was empty?

By this time you are perhaps beginning to be puzzled. You may even be saying to yourself, "Wood, air, and water are alike, and an empty glass isn't empty. Is this sense or nonsense?" But there are more puzzling things to come. Do you think it is possible to pass sugar through a handkerchief without tearing the handkerchief? Perhaps you say, "No. Sugar can't be passed through a piece of cloth." But it can be done if you know how to do it. You will see that these statements are correct when you study this unit.

Problem 1:

HOW ARE ALL MATERIALS ALIKE?

We have said that wood, water, and air are alike. When you look at these materials, you see at once that they do not look alike. A wood block is solid material. If you place it on the table, it keeps its shape and it stays there. If you pour water on the table, it makes a puddle or runs off on the floor. It does not have any shape of its own. You cannot see air at all. You cannot cut off a piece of air and put it on the table. But you know that there is air around us because you can feel it. You also fill your bicycle tires with air.

So far you have seen only the ways in which air, water, and wood are different. Now how are these materials alike? If you pick up a block of wood, you notice that it weighs something. Of course, a small block of wood weighs very little. A large wooden table may have more weight than you can lift. How about water? Does it have weight, too? You do not need to experiment to discover whether water has weight. Everyone knows that a bucket of water weighs more than a bucket of air. So far, you can easily see that water and wood are like each other in at least one way: they both have weight.

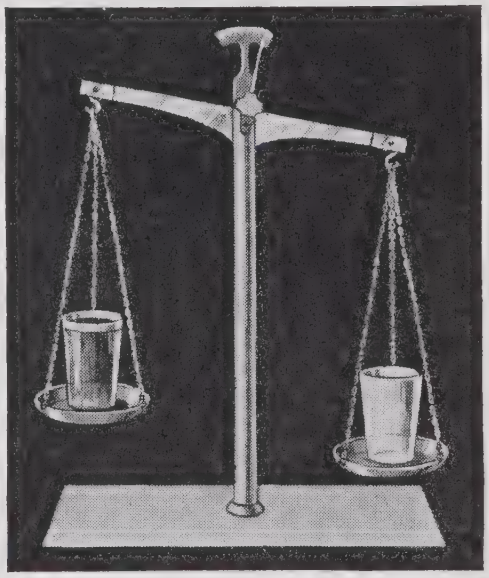


Fig. 65. What is wrong here? The glass at the left contains water. The one at the right has only air in it.

It is not so easy to see that air also has weight. A

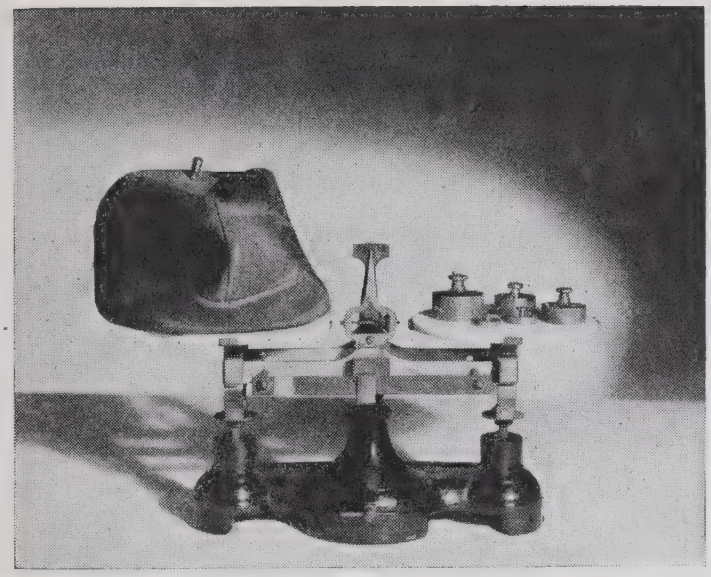
handful of air does not seem to weigh anything. Of course, you would not expect such a thin material as air to weigh much. Since we cannot tell whether air has weight by lifting it with our hands, we shall have to discover some way to weigh it. Can you think of an experiment to show that air has weight?

If we could do so, we would let you work out for yourself all the experiments needed to answer your questions. But this would take so much time that you would not be able to get very far in your study of science. So we shall do the next best thing. We shall tell you how to do most of the experiments to solve your problems. Your part of the work will be to follow directions carefully and to see why each experiment is done the way it is. In all scientific work it is very important to follow directions exactly. You will also want to watch carefully, so that you will know just what happens. Then you will be able to decide what is the right answer to your problem.

After you have learned how to do one experiment for yourself, you will probably be able to think of other ways of doing the experiment or of other experiments to show the same thing. You will then be thinking and acting like a scientist.

And now let us come back to our problem, "Does air have weight?" You can solve this problem by doing an experiment.

Experiment 1. *Does Air Have Weight?* Get a football or a basketball, and a balance or pair of scales. Squeeze most of the air from the football and place it on one pan of the balance. Also place on the pan the rubber band or string or whatever is used to keep the air from leaking from the football when it is pumped up. Add weights to the other



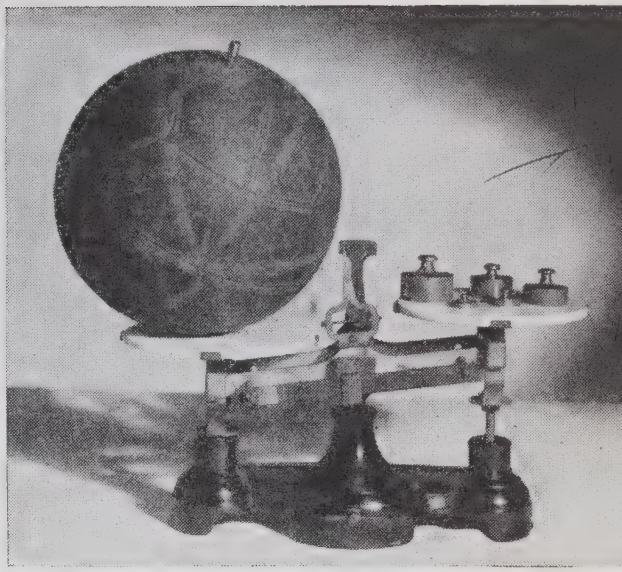


FIG. 66. Apparatus for Experiment 1

pan until the two pans are in balance. (Small pieces of paper or tin-foil may be added to get an exact balance.) Now pump the football full of air and tie it shut. Then put it back on the balance. Does the football weigh more than it did, or less? Or does it weigh the same as it did? How do you know? How do you explain what happened?

Now you are ready to believe that wood, air, and water are alike in at least one way: they all have weight. Of course, this is true of all materials. In fact, you can define a material as anything that has weight. Light, sound, and odors, of course, are not materials. They have no weight.

There is still another way in which all materials are alike. Let us suppose we have a box and some wooden blocks. We begin putting the blocks into the box. Finally, we cannot put any more blocks into the box. It is full. Why is this true? This is true because each block takes up a certain amount of room or space. There is only a certain amount of space in the box; therefore, the box will hold only a certain number of blocks. Water

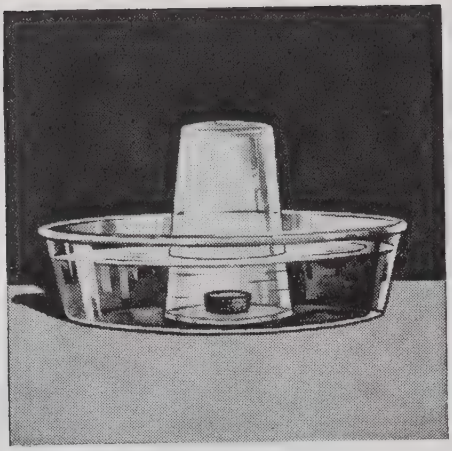


FIG. 67. Experiment 2

also takes up space. A glass will hold only a certain amount of water. After the water has taken up all the room in the glass, no more can be added.

It is easy to see that wood and water take up space, but what about air? Does it take up space, too? And if it does, how can we prove it? We can prove it by doing what Henry did when he proved that the glass which appeared to be empty was not really empty.

EXPERIMENT 2. *Does Air Take Up Space?* Get a large jar or pan three or four inches deep and fill it nearly full of water. Also get an ordinary drinking glass and a flat cork. Put the cork on the water. Now place the open end of the glass over the cork and push the glass downward into the water. Watch the cork in the glass. Does the water rise in the glass so that it becomes filled? What stops the water from rising in the glass? Is it correct to say that the glass is empty? How does this experiment prove that air takes up space?

If you have understood all that you have studied, you have discovered that all materials are alike in two ways: (1) They have weight, and (2) they take up space. Such things as light, heat, sound, and electricity are not materials. They do not weigh anything, and they do not take up space. Later in your science work you will learn what they are. You can now answer some of the introductory exercises that you could not answer before you studied this problem.

Self-Testing Exercises

1. In what two ways are all materials alike?

2. Tell how you did or could do an experiment to show that air has weight.

3. Tell how you could show someone that air really fills space.

4. When a scientist makes a statement, he expects to be asked, "Why do you believe that?" So he is always ready to back up his statement with proof. This is a good habit for all of us to have. It is also a good idea to ask other people their statements. "How do you know?" is a good question to ask.

Do you believe or not believe that all materials take up space? Why do you believe as you do? Give several reasons.

5. Do you believe or not believe that all materials have weight? Why do you believe as you do? Give several reasons.

Problems to Solve

1. With a vacuum-pump you can pump almost all the air from a bottle. How can you do an experiment in which a vacuum-pump is used to prove that air has weight?

2. In Figure 68 the two tumblers are standing in a pan of water. Tumbler B has water in it, while Tumbler A has only air in it. How could you fill Tumbler B with air and Tumbler A with water without taking them out of the water? Prove your answer by actually doing the experiment.

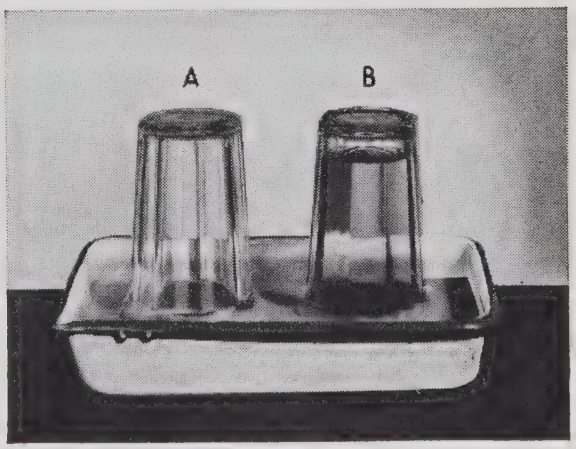


FIG. 68. Apparatus for Problem 2

3. Suppose there are two corked bottles that look exactly alike. You are told that one bottle contains air and that the air has been pumped out of the other bottle. How can you tell which bottle contains air?

Problem 2:

WHAT ARE SOLIDS, LIQUIDS, AND GASES?

So far we have seen that materials take up space and have weight. But although all materials are alike in these ways, they are different in other ways. Wood, water, and air take up space and have weight, but in some ways each is different from the other. The scientist says that wood is a *solid*, water is a *liquid*, and air is a *gas*. You have already heard these words many times. But just what is a solid? How does it differ from a liquid? And how is a gas different from the other kinds of materials?

What is a solid? To answer these questions, we must first find what *characteristics* each of these materials has. Do you understand what the word "characteristics" means? You may have brown hair, brown eyes, a pug nose, be five feet tall, and weigh 100 pounds. These are some of your characteristics. It is by your characteristics that other people know who you are. A solid has certain characteristics, and a liquid has certain characteristics. Gases have characteristics that are different from those of solids and liquids. Let us see what these characteristics are.

Bricks, chairs, and pencils are solids. They do not look very much alike, but they are alike in two ways: (1) Each of them takes up a definite amount of space, that is, each has a certain size; and (2) each of them has a shape of its own. It makes no difference where you place a chair so far as its size is concerned; its size remains the same. It makes no difference where a chair is placed so far as its shape is concerned; it keeps its own shape wherever it is placed. Materials that keep their shape

FIG. 69. Which objects in this picture are alike? Which objects are very different from some of the others. Be ready to give the *characteristics* that make some of the objects like other objects or different from them.

are said to be solids. Bricks, chairs, iron, and pencils are solids, and each has the characteristics of a solid.

Some people think that a material is not a solid unless it is hard or firm. You can see, however, that these people do not have the right idea of what a solid is like. For example, a wet piece of clay or a piece of fresh bread is neither hard nor firm, yet each is in solid form; that is, each keeps its own shape. Everything that has a definite size and has its own shape is a solid.

WHAT IS A LIQUID? Water, as you can see, cannot be called a solid. It takes up space, but it has no shape of its own. If it is poured on a flat surface, such as a table, it will run over the table and on to the floor. If it is poured into a bottle, it will take the shape of the part of the bottle that it fills. If it is poured into a pan, it will take the shape of the part of the pan that it fills. It always takes the shape of the bottle or pan or other container into which we put it. Any material that fills up a definite amount of space, but has no shape of its own, is a liquid.

FIG. 70. Balloons filled with gas are used frequently to explore the upper air, or *stratosphere*. The men who go up in them take instruments for measuring temperature, wind, and air pressure. Balloons carrying men have risen over thirteen miles. The balloon comes down when the pilot lets some of the gas escape from the balloon.

WHAT IS A GAS? A gas, such as air, is quite different from a solid or a liquid. A gas has no shape of its own. In this way it is like water, but it is different from water in one important way. Air has no definite size. Now let us see if we can understand what this means. We will suppose that we have a room from which we can pump out all of the air. In this room we put a tightly corked bottle full of air. Then we pump all of the air from the room. We now have a room containing no air, except the air in the bottle. Suppose we then remove the cork from the bottle. What do you think will happen to the air in the bottle? Will it stay in the bottle, the way water would, or will it spread through all the room?

The answer is that the air in the bottle would spread to all parts of the room. There would be some air, therefore, in every part of the room. Of course, the air in the room would be much thinner than it was in the bottle. That is, the little particles that make up the air would be much farther apart in the room than they were in the bottle.

We are now ready to make a definition for "gas." Any material that has no definite size or shape is a gas.

There are many different kinds of gases. Some gases you can see because they are colored. Some of them you can smell, for example, the gas that comes from your kitchen gas stove. Some gases can be neither seen nor smelled. If an automobile engine is left running in a closed garage, the garage will quickly fill with carbon-monoxide gas. You cannot see the gas or smell it, but it will quickly kill you. Scientists have found hundreds of uses for the different gases that have been discovered. They are used to fill balloons and dirigibles, to give us light and heat, to put us to sleep while the dentist repairs our teeth, to make soda-water ("pop"), and for many other purposes.

Self-Testing Exercises

1. Make three columns on your paper. At the top of one column write the word "A Solid"; at the top of the next column write "A Liquid"; and at the top of the third write "A Gas."

In each column write the characteristics that belong to that kind of material. The following list gives the characteristics: (*a*) Takes up space. (*b*) Has a definite size. (*c*) Has weight. (*d*) Takes the shape of the container that holds it. (*e*) Has no definite size. (*f*) Has no definite shape. (*g*) Has a definite shape. (*h*) Fills any vessel in which it is put.

2. (*a*) In what way is a solid different from a liquid? (*b*) In what ways is a solid different from a gas? (*c*) In what way is a liquid different from a gas?

3. Which of the following materials are solids? Liquids? Gases? Iron, glass, milk, honey, air, paper, a sponge, oil, vinegar, oxygen.

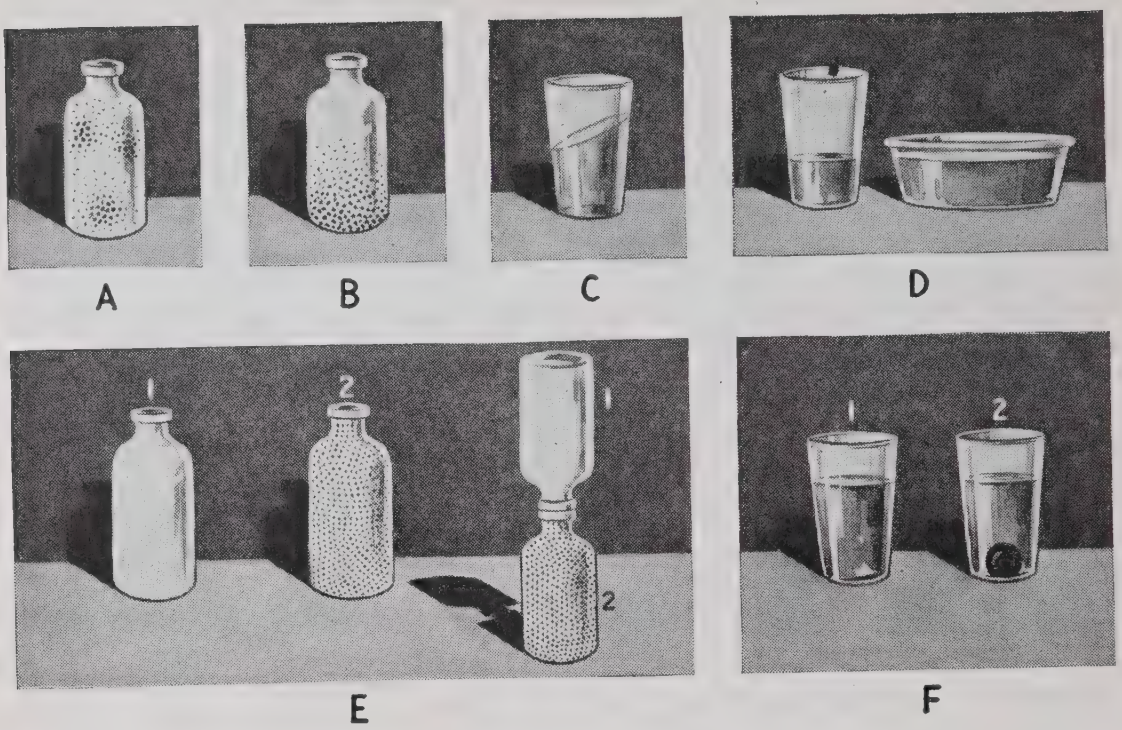


Fig. 71. Each of these drawings is wrong in some way. The problems below tell you what to do.

Problems to Solve

1. Drawing A of Figure 71 represents a bottle of air. The little dots in the bottle are particles of air. What is wrong with this drawing? Make a drawing that is correct.

2. Drawing B represents a bottle of air. The little dots are particles of air. Make a correct drawing.

3. Make a correct drawing of the glass of water in C.

4. Refer to Drawing D of Figure 71. All of the water in the pan was poured from the glass. Make a correct drawing.

5. In Drawing E Bottle 1 contains no air. Bottle 2 contains air, represented by the small dots. Bottle 1 is then placed over Bottle 2, as shown in the drawing, so that air from Bottle 2 can enter Bottle 1. Make a correct drawing.

6. In Drawing F Glass 1 contains water. Glass 2 contains an equal amount of water with an iron ball in it. Make a correct drawing.

FIG. 72. To make sodas, solids must be dissolved in liquids. And a gas must be dissolved in a liquid, too, as you will learn later.

Problem 3:
WHAT IS A SOLUTION?

WHAT ARE THE CHARACTERISTICS OF A SOLUTION? You have been using *solutions* all your life. Every time you put sugar in lemonade, cocoa, or chocolate, you are making a solution. If you live on a farm, perhaps you have helped spray potato plants or fruit trees to keep them from being eaten by insects and worms. If you have done so, you were probably using a solution. Many times you have put some solid material into a liquid and have seen the solid disappear.

Solutions are so important to you that you could not stay alive without them. You cannot use the food you eat nor the air you breathe until they are in the form of solutions. You will learn many things about the use of solutions, but first let us learn what a solution is.

We shall first think about what happens when your mother makes a cup of tea. She boils some water in a kettle. While it is heating, she measures out some tea leaves and puts them into the tea-pot. The boiling water is poured into the pot and allowed to stand for a few minutes; then the tea is poured. Usually a little sugar or lemon is added, and the tea is ready to drink (if it isn't too hot).

As you look down into the cup, the liquid is the same color all the way through. If you take a spoonful from any place in the cup, it tastes the same as a spoonful from anywhere else in the cup. And they should taste alike, because they are the same. What you have is a solution. In this solution there are three materials: water, tea, and sugar. But you cannot tell by looking at the solution what is in it. The sugar has disappeared, and the liquid no longer looks like water.

So far we have not learned anything about a solution that we did not already know. Perhaps we had better examine some tea more carefully.

Experiment 3. *What Are the Characteristics of a Solution?* (*a*) Place some tea leaves in the bottom of a beaker. Add hot water. Observe what happens. Does the water change to a yellow color all at once? Or can you see the color gradually spread throughout the water?

b) Line a clean glass funnel or a small tin funnel with *filter paper* or clean towel paper and place the funnel in a test-tube. Be sure to fold the paper as shown in Figure 73 so that no material can get through the funnel without going through the paper. Wet the paper with clear water so that it will stay in place in the funnel. Carefully pour some of the tea solution into the filter paper. Now examine the liquid that

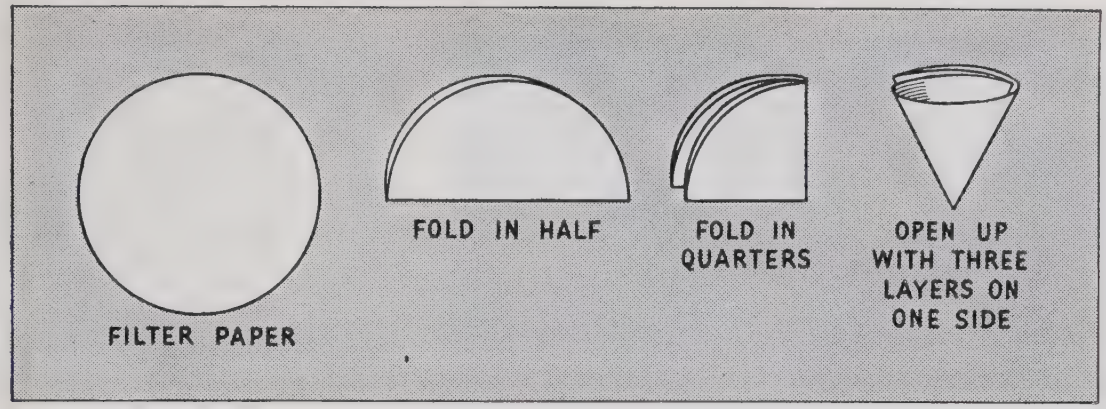


FIG. 73. Directions for folding filter paper

comes through the filter paper. (1) Is it still yellow, or did the colored material from the tea stay on top of the filter paper? Taste the filtered liquid. Is there tea in it? (2) Hold the tea solution up to the light. Is it clear or cloudy? Can you see any particles floating in it? If you have a compound microscope, put a drop of tea on a glass slide and look for yellow particles in the solution. Are they large enough to be seen with the microscope?

c) Let the test-tube of tea solution stand for several days. Does it remain the same color, or does the material from the tea settle to the bottom? Taste some of the solution by taking a little of the liquid from the top. Can you still taste the tea?

Write down three characteristics of the tea solution which you think are true of all solutions.

d) Now make two more solutions to see if they have the same three characteristics as tea solution. For one use a spoonful of sugar and for the other, a lump of copper sulphate. (Copper sulphate is used because it makes a blue color.) Do with each solution what you did with the tea in parts *a*, *b* and *c*. (*Do not taste the copper sulphate. It is poisonous.*) Answer the same questions about the sugar solution and the copper sulphate solution that you did for the tea solution. In what ways are all three of these solutions alike?

FIG. 74. Water can dissolve rock just as it dissolved the sugar in Experiment 3. Mammoth Cave, Kentucky, and many other caves in our country are striking examples of how rock is worn away when water dissolves the rock and carries it away.

We can describe what happens when a material *dissolves* by telling what happened to the sugar in Experiment 3. Tiny particles of sugar broke off from the grain of sugar and mixed with the water. This kept up until the grain of sugar was all dissolved. Since the tiny particles were too small to be seen, the sugar disappeared. The sugar particles mixed with all of the water; therefore, any teaspoonful of the solution had the same amount of sugar in it as any other teaspoonful. What is true of sugar is true of other materials when they dissolve in liquids. The solid dissolves and spreads evenly all through the liquid to make a solution.

The experiments you have done show you that solutions have three important characteristics: (1) The liquid is clear; that is, the particles of the dissolved solid cannot be seen even with a compound microscope. (2) The particles are so small that they pass through filter paper. (3) The particles stay all through the liquid; they do not settle to the bottom or rise to the top even when the liquid is allowed to stand for several days. These three statements describe a solution. They tell us what the characteristics of a solution are.

To understand the characteristics of solutions better, let us try putting another kind of solid in water to see what happens. For this experiment use laundry starch and water. You have probably heard someone speak of dissolving starch in water to stiffen clothes. But "dissolve" is not the right word to use when we mix starch and water. You will see why it is wrong when you compare a mixture of starch and water with the solutions you made in Experiment 3.

Experiment 4. *How Do We Know That a Mixture of Starch and Water Is Not a Solution?* (*a*) Powder the starch and stir it thoroughly into cool water. Notice whether the mixture is clear or cloudy.

b) Pour a small quantity of the starch mixture into a test-tube and add a drop of iodine solution. The mixture turns blue. (Cool starch always turns blue or blue-black when iodine touches it. No other substance does this. Therefore we use iodine to show whether we have starch. It is called a "test" for starch.) Now filter some of the remaining starch mixture (not the mixture that was tested with iodine). Add a

Fig. 75. Before cities can use river water for a water supply, the mud and other impurities must be removed. To help do this, water is pumped into large settling basins, where it stands for some time. Which would settle to the bottom of the basin, dissolved materials or undissolved materials? How do you know?

FIG. 76. From the faucet the attendant is drawing "soda-water," or water with carbon dioxide dissolved in it. A tank of carbon dioxide is connected with a supply of water in such a way that a solution of carbon dioxide and water comes out when the faucet is opened.

Some of the carbon dioxide gas immediately bubbles out of the solution when it comes out of the faucet.

drop of iodine solution to the liquid that passes through the filter paper. Does the starch pass through the filter paper? How do you know?

c) Let some of the unfiltered starch mixture stand in a test-tube for several days. Does the starch settle?

Give three reasons why you think the starch did not dissolve in the water.

CAN GASES DISSOLVE IN LIQUIDS? Just as this book was being written, the people in a certain part of Illinois began to notice a strange taste in their drinking water. The water came from wells. Scientists were asked to find why the water had this strange taste, and this is what they discovered: For some reason a gas had formed down in the earth. This gas had slowly worked its way through the soil and into the wells, where it dissolved in the water.

Gases, as well as solids, can dissolve in liquids. You have seen some of the dissolved gas come out of a liquid. When you open a bottle of "pop," you see bubbles of carbon-dioxide gas rise to the top. Sometimes the bubbles come up so fast that the "pop" foams over the top.

FIG. 77. On drug-store shelves there are rows and rows of bottles filled with solutions. Much of the medicine given by doctors is in solution, in order to give exact amounts of drugs. These drugs are dissolved in many different kinds of liquids.

This dissolved carbon-dioxide gas gives the "pop" its sharp, stinging taste. When you heat water, little bubbles form on the bottom and sides of the pan. These are bubbles of air that have been dissolved in the water. As you go on with your science work, you will learn of many ways in which we use gases dissolved in liquids.

WHY DO WE USE DIFFERENT KINDS OF SOLUTIONS? Did you ever try to get wet paint off your hands with water? If you did, you found that it would not work. But you can try some turpentine or gasoline or kerosene. The paint will disappear like magic. Why do you suppose these liquids will remove the paint, while water will not remove it? Let us see what an experiment will show us.

EXPERIMENT 5. *How Can We Dissolve Materials That Do Not Dissolve in Water?* (*a*) Get a small lump of gum camphor. Fill one test-tube half full of water and another half full of

FIG. 78. In modern dry-cleaning establishments, clothes are rotated in large cylinders with liquids that dissolve the grease. The bottles on the shelf at the left contain various kinds of liquids that are used to dissolve stains and remove them by hand.

alcohol. Drop a small piece of camphor into each test-tube. Put corks in the two test-tubes, shake them, and allow them to stand overnight. What happens?

b) Get some butter or lard. Fill one test-tube half full of water, another half full of alcohol, another half full of gasoline, and another half full of carbon tetrachloride. (Carbon tetrachloride is sold as cleaning fluid under the name "Carbona.") Place a small piece of butter or lard in each tube. Shake the tubes and allow them to stand overnight. In which liquid does butter or lard dissolve the best?

This experiment shows you why we use gasoline instead of water to remove grease from our clothing. Water will not dissolve grease. Gasoline will. Water is the greatest dissolver in the world. It will dissolve more

kinds of substances than any other liquid, but there are many substances that water will not dissolve. Therefore, scientists have spent much time in discovering what liquid or liquids will dissolve materials that they want to dissolve. For example, there could not be any rubber cement until someone discovered a liquid that would dissolve rubber. There was no iodine for cuts and sores until someone discovered that alcohol dissolves the hard iodine crystals. And, as you will see in Table 1, below, we would have a hard time removing stains from our clothing if we did not know how to dissolve the materials in the stains.

You can see that when we want to make a solution, we must know what liquid will dissolve our material. Chemists have experimented with different kinds of materials, and have discovered what liquids will dissolve different materials. It would take too much space to tell about all of the different kinds of liquids that are used to dissolve materials. But you will be interested in what has been discovered about liquids that will remove common spots and stains. To remove a stain, you must know first what kind of stain it is; then you can select the liquid that will dissolve it.

TABLE 1. How to Dissolve Common Spots and Stains

Kind of Spot or Stain	Liquid
Blood	Solution of salt
Cocoa	Boiling water
Fruit stains	Boiling water
Grass stains	Ether or alcohol
Grease	Carbon tetrachloride
Paint	Turpentine
Tea or coffee	Boiling water

FIG. 79. Rubber cement, made of rubber dissolved in benzene, is an important material for making rubber boots. The cement is applied to pieces of the boots, which are then pressed together. When the benzene evaporates, a film of rubber holds the pieces together.

You have found out many things about materials. You have learned that all materials take up room and have weight. Materials may be in the form of a solid, a liquid, or a gas. Solids, liquids, and gases may dissolve in liquids to make solutions.

Self-Testing Exercises

1. What are three characteristics of a solution?
2. How do you know that a mixture of starch and water is not a solution?
3. Why can you not see the particles of a dissolved solid?
4. Give two different examples of a gas dissolved in a liquid?

5. Why is the camphor solution (spirits of camphor) that the drug store sells made with alcohol instead of with water?

6. Name at least two liquids (besides water) that are used in your home to dissolve materials. Think of varnishes, cleaning fluids, etc.

7. Which of the following materials do you think are dissolved in the liquid?

a) Mud in water
b) Salt in ocean water
c) Sweetness and color in molasses
d) Coloring in fountain-pen ink
e) White material in milk
f) White or colored material in paint

If you do not know, how could you find out?

Problems to Solve

1. A mechanic who has been repairing a greasy engine first washes his hands with kerosene. After that he washes with soap and water. Explain why he washes with the kerosene before using water.

2. When the varnished surface of furniture is scratched, you can usually rub the scratch out by using a cloth wet with alcohol. Explain.

3. The water in the ocean is salty. Explain why a layer of salt does not settle on the bottom of the ocean.

4. Make as long a list as you can of solutions that are used in your home.

5. Perfectly clear water is being used in the boilers of some locomotives. The engineers discover that the insides of the boilers are becoming covered with a coating of minerals from the water and soon will be ruined. Someone suggests that the water be filtered to remove the minerals. Will this plan work? Why?

6. In getting salt from the ground in some places, water is pumped into wells and then pumped out again. How do you suppose they get the salt from the water?

Problem 4 (Optional):

HOW ARE MATERIALS PUT TOGETHER?

You notice that Problem 4 is labeled "Optional." In the first three problems you learned about solids, liquids, gases, and solutions. This problem is included for those who want to learn more about materials. In this problem there are explanations of some of the facts that you have observed about solutions.

In Experiment 3 the lump of copper sulphate sank to the bottom of the glass when it was dropped into water. You would expect this, since it is heavier than water. As you watched the lump, a blue color appeared in the water around it. This blue color spread upward through the water. This action raises a question: How can copper sulphate move upward through the water? Since it is heavier than water, you would expect it to remain in the bottom of the glass. You also found that the lump of copper sulphate disappeared. What became of the copper sulphate? To answer these questions, you must understand how materials are put together.

What is the molecular theory? Since you are only beginners in the study of science, it would hardly be fair to ask you to figure out an explanation for these facts. When scientists have an explanation that seems to be true, but cannot be proved absolutely, the explanation is called a *theory*. It may still be called a theory even after everyone is sure it is correct. Let us see what theory scientists use to explain materials, or *matter*, as they say.

First of all, scientists believe that all kinds of matter, or materials, are made of particles. These particles are called *molecules*. Therefore this theory is called the

molecular theory of matter. Molecules are so small that they cannot be seen with the most powerful microscope. A few illustrations may help you to realize how small molecules really are. One scientist has said, "If a drop of water were magnified until it was as big as the earth, the molecules would be only as big as baseballs." In one breath a person takes about 108,000,000,000,000,000,000,000 molecules of air into his lungs. There are about as many molecules in a thimbleful of water as there are sand grains in two and one-half cubic miles of sand. It is also estimated that if the molecules in a pint jar of air were allowed to escape from the jar at the rate of 10,000,000 per second, it would take 40,000,000 years to empty the jar.

FIG. 80. The dots in the drawing represent a few of the molecules in a glass of air. Each arrow shows the direction in which the molecule is moving.

These numbers are almost impossible for us to imagine. But if you get the idea that molecules are smaller than anything you ever imagined, and that the smallest bit of matter which you can see with your naked eye is composed of millions of molecules, you will have a fair idea of how small they are.

Second, scientists believe that there are spaces between the molecules of matter. As you would probably expect, the spaces between the molecules of a gas are larger than those between the molecules of liquids. The spaces between molecules of liquids are larger than those between molecules of solids. It is rather hard to believe

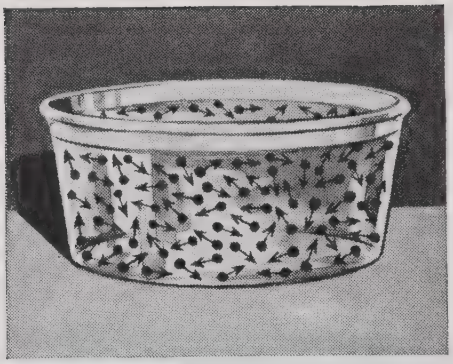


FIG. 81. The dots represent a few of the molecules in a dish of water. Notice that they are closer together than in Figure 80.

that materials such as gold or iron really have spaces in them. However, if a piece of gold is placed in a dish of mercury (the silver-colored liquid used in thermometers), the mercury will go into the gold; that is, its molecules will go in between the molecules of gold. As you will learn later, there are other reasons for believing that there are spaces between the molecules in all kinds of matter.

Another part of the molecular theory is that the molecules of all kinds of matter are always moving. It is easy to believe that the molecules of a gas or a liquid can move and do move. It is harder to believe that the molecules of a hard metal, such as iron, gold, or silver, are moving. But they really are moving all the time. One reason for believing that the molecules of metals are moving is this: When a brass spoon is covered with silver, chemists find that a very small amount of the silver has made its way into the brass. There is only one explanation: The molecules of silver must have moved into the spaces between the molecules of the brass.

And now let us bring together the different parts of the molecular theory: (1) All matter is composed of tiny particles called molecules. (2) There are spaces between molecules. (3) The molecules are always moving. Now you are ready to explain what happened in your experiments. If the molecular theory is a good one, it should explain the facts that you observed.

HOW DOES THE MOLECULAR THEORY EXPLAIN SOLUTIONS? Now you can understand what you saw happen in Experiment 3. Molecules of the copper sulphate separated from the lump and went into the spaces between the molecules of water. But even then they did not stop. They kept bouncing around among the molecules of water until some of them finally got to the top of the water. More and more molecules separated from the lump and went into the spaces between the molecules of water until finally the lump was gone. When the glass was held to the light, no solid particles could be seen, because molecules are so tiny.

This is what takes place in all solutions. The molecules of the solid pass in between the molecules of the liquid and travel to every part of the liquid. They are moving rapidly, and they are kept apart from each other by the water; therefore they do not settle to the bottom even though they are heavier than the water.

The molecular theory also explains why a solution can be filtered while a mixture cannot. In a solution the particles are in the form of molecules. The molecules are so tiny that they can pass right through small holes in the filter paper. In a mixture the particles are hundreds or thousands of times larger. They cannot pass through the filter paper.

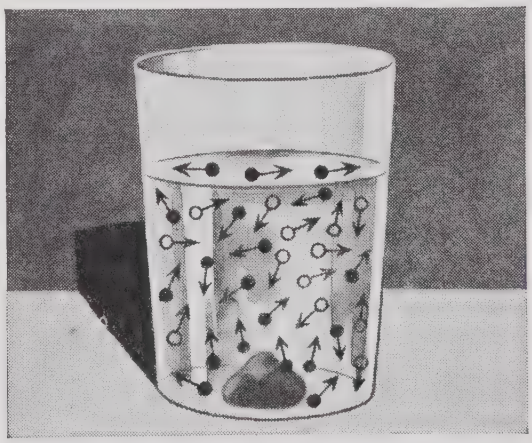


FIG. 82. This picture shows copper sulphate molecules going into the spaces between the molecules of water (shown as white circles).

We have seen that the molecular theory does explain the facts we observed in our experiments. If we are good scientists, we will not accept the theory until we have tried it out to see whether it fits many other facts. Let us, therefore, see how the theory works in explaining other things that we know.

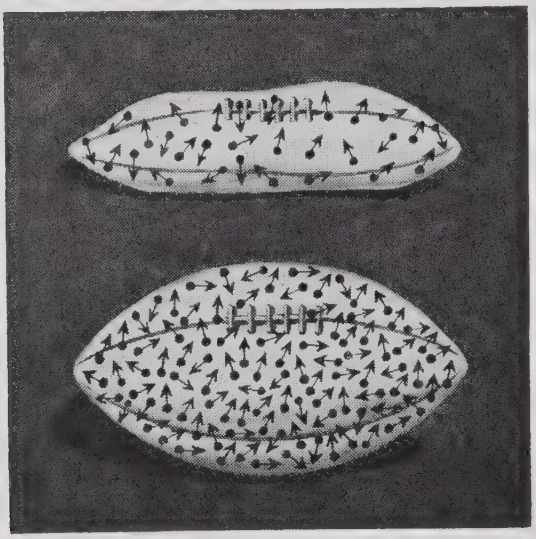


FIG. 83. After you have blown up a football, there are many more molecules of air in it than there were before.

If an unlighted gas jet is opened, in a very short time you smell the gas in all parts of the room. Have you ever come home from school and said, as you opened the door, "We are going to have onion soup for supper"? In both cases molecules must have entered your nose—in one case molecules of gas and in the other case molecules of onion. To get to your nose they must have moved through the air. The molecular theory explains these facts satisfactorily.

You have probably noticed that after an automobile tire has been pumped up, it is still possible to force in more air. How can this be explained? The pump pushes more molecules of air into the tire. When this happens, the molecules of air in the tire must be crowded closer and closer together. This is clearly explained by our theory, which says that there are spaces between the molecules. Scientists use the molecular theory in many ways to explain how matter acts. You will use the theory many times in your science work.

To learn a theory, you must use it in your thinking. You must be able to use it to explain things that are taking place about you. To be able to do this, you must practice using the theory to explain things. Below you will find common happenings for you to explain by the molecular theory. These will give you a chance to practice using the molecular theory.

Self-Testing Exercises

1. What word do scientists use to stand for all materials?
2. Why do scientists think up theories?
3. How is a theory different from a fact?
4. What is the molecular theory?
5. Explain the following by using the molecular theory:

a) A small amount of coloring matter may color a whole glass of water.
b) Mercury can go into gold.
c) Silver can be found in the metal upon which it is plated.
d) The odor of perfume spreads throughout a room.
e) An air-pump can force air into a tire that already has much air in it.

6. Why do you think that the molecular theory is probably true?

Problems to Solve

1. If a little sugar is added to water, it disappears. If you hold the mixture to the light, you cannot see the particles of sugar. Why not? If the mixture is run through a piece of porous paper, like towel paper, no sugar is found on the paper. Explain.

2. Air, as you probably know, is a mixture of various kinds of gases: oxygen, nitrogen, water vapor, carbon dioxide, and others. Carbon dioxide is much heavier than the other gases. Why is the carbon dioxide mixed all through the air instead of being collected near the ground?

3. If a lump of sugar is added to a cup of coffee, the coffee soon becomes sweet in all parts of the cup. Explain.

4. If moth balls are placed in the pocket of a coat in a closet, the smell of the moth balls soon spreads to all parts of the closet. Explain.

5. Your mother does not put cooked cabbage in the ice-box because it will give butter the taste of cabbage. Explain how the butter takes on the flavor of cabbage.

6. A boy brought home a rubber balloon filled with hydrogen gas. When he went to bed, the balloon was tightly filled and floating against the ceiling of the room. When he awoke next morning, the balloon had lost most of its hydrogen and was lying on the floor. The boy could find no hole in the balloon. How could the hydrogen have escaped?

7. If the hole in the bottom of an ordinary red flower-pot is sealed with wax and the pot is filled with water, the outside of the pot soon becomes moist. Explain how the water can get through the pot.

8. You know that a wet cloth soon dries. Is this fact explained by the molecular theory? How?

LOOKING BACK AT UNIT THREE—SUMMARY EXERCISES

Here is a suggestion that will help you to look back at Unit Three to see what new ideas you got from it: Give a good answer to each big problem of the unit. Use several sentences for an answer if you really need them. The questions below will help you.

1. How are all materials alike?

2. What is a solid? A liquid? A gas?

3. What are the characteristics of a solution? How do we use solutions?

4. (Optional) What are molecules? How do they behave in solids? In liquids? In gases? How do they behave when a material dissolves?

FIG. 84. Exercise 3

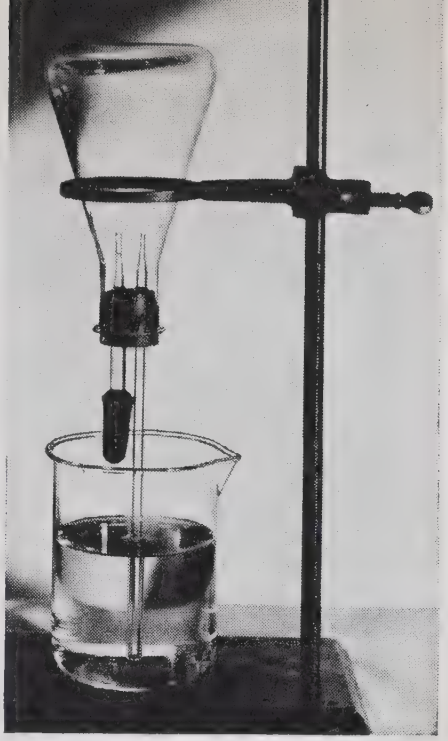


FIG. 85. Exercise 4

ADDITIONAL EXERCISES

1. Fred was filling a bottle with water. The funnel he was using fitted tightly in the neck of the bottle. Even though he had the funnel full of water, it ran into the bottle very slowly. Which characteristic of matter did Fred forget? How could he have filled the bottle more quickly?

2. In this unit you learned that all matter has two characteristics: it fills space, and it has weight. Every material has at least two other characteristics. Find out what they are?

3. Arrange an apparatus as shown in Figure 84. Heat the ammonia solution in the flask slowly until it begins to boil. The bottle will then be filled with almost pure ammonia gas. Keep the mouth of the bottle downward and set it in a pan of cool water. What becomes of the ammonia?

4. Make an ammonia fountain. Prepare a bottle or flask full of ammonia as in Exercise 3, but close the mouth with a rubber stopper arranged as shown in Figure 85. Place the end of the tube in a pan of water and squeeze the water from the medicine dropper into the flask. Explain what happens.

5. If all materials have weight, how can you explain why a balloon filled with hydrogen gas goes up instead of down?

6. What is the difference between the meaning of the word *liquid* and the meaning of the word *fluid?*

7. What is likely to be one difference between rain water and well water?

8. According to Problem 1, two materials cannot be in the same place at the same time. When you make a solution of sugar in water, are not the sugar and water in the same place? Explain your answer.

9. Make a "crystal basket." First, make a small basket of cotton-covered copper wire and small string of thread. Make it small enough to go inside a large beaker. Make enough hot solution of copper sulphate to cover the basket. Keep adding copper sulphate to the solution until it is very strong. Lower the basket into the solution and allow it to cool slowly. Will hot water or cold water usually dissolve the most material?

10. How does a dissolved solid change the boiling point of water? Find out how hot water gets while it is boiling by holding a chemical thermometer in boiling water. Then add two or three tablespoonfuls of salt or sugar. How does the temperature change?

11. Plan and try an experiment to see if a solution of salt or sugar freezes at the same temperature as water.

12. Make some lemon "soda water." Obtain a clean bottle with a screw top or some other kind of top that can be held on against considerable pressure from the inside. Put one teaspoonful of baking soda in the bottle and fill it half full of cool water. Now pour in four teaspoonfuls of lemon juice and fasten the top on quickly.

Watch what happens. When the action in the bottle has stopped, pour some of the water out into a glass and see what happens. What kind of a solution did you make?

13. Suppose that you were given a test-tube containing a liquid and were asked if the liquid had materials in solution. Work out an experiment to help answer the question.

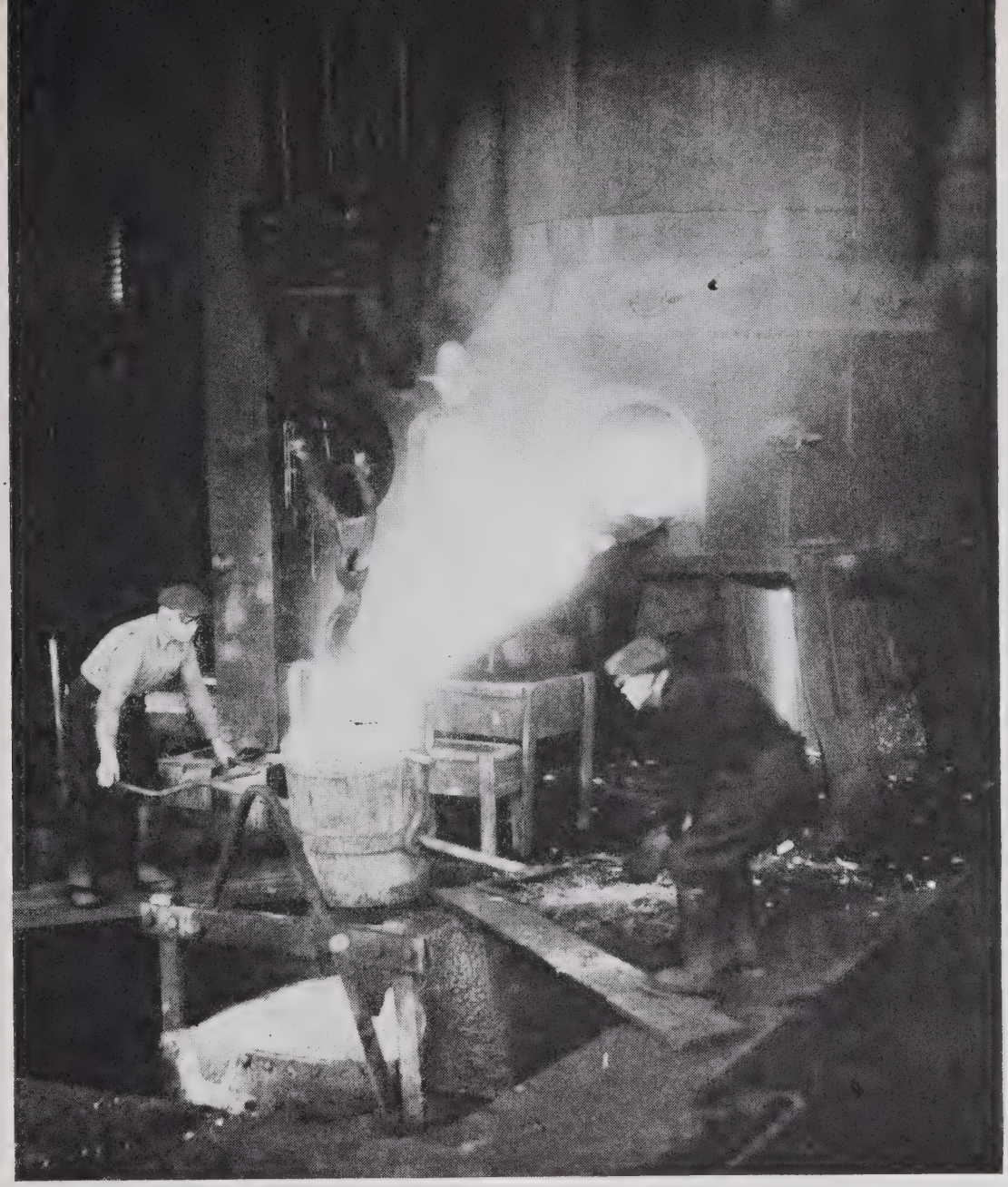


FIG. 86. These workers are "tapping" a blast furnace. This means that they are drawing off the heavy melted iron from an opening in the bottom of the furnace. From this picture you can see that the melted iron is very hot. A temperature of more than 3000 degrees is needed to melt the iron ore and the other materials mixed with it.

UNIT FOUR

UNIT 4

HOW DO HEATING AND COOLING CHANGE MATERIALS?

INTRODUCTORY EXERCISES

1. We usually tell how hot or cold it is by looking at a thermometer. The liquid in the tube moves up when the temperature gets warmer and moves down when it gets cooler. Why does the liquid move as the temperature changes?

2. If a pan of water is left uncovered for a few days, what will happen? Explain.

3. Telephone wires strung between poles sometimes snap in very cold weather. Explain.

4. If a thick drinking glass is placed in very hot water, it will usually crack. Explain.

5. How could you prove whether or not there is any water in the air in your school-room?

FIG. 87. Probably you have seen a concrete pavement, or a sidewalk, that has bent and cracked like this one. Did you know that heat caused this surprising thing to happen? In this unit you will find out how heat changes the concrete.

LOOKING AHEAD TO UNIT FOUR

SUPPOSE someone asked you if you could change a quart of water into more than a quart of water. What would you say? You know that a certain amount of water will take up just so much room, or space. Would it be possible to make a quart of water take up more space? According to what you have learned, this seems impossible. Maybe it is impossible, but, if so, how do you explain this experience that Betty had?

Betty's mother told her to put some water on the stove to heat. She filled the kettle with water, placed it on the stove, and went into the other room to read. After awhile she heard a sputtering, hissing noise in the kitchen. Much to her surprise, she found that the water was running out from the top of the kettle. There must have been more water in the kettle than there had been

when Betty put it on the stove. Does this seem to show that you can make a quart of water into more than a quart of water?

If you can get a rubber balloon, try this experiment. Fill the balloon with air and then hold it over a hot stove. You will see that the balloon gets larger. If you get it hot enough, it may burst. Now how do you explain this? Of course we know that air occupies space. We know that if we put more air into the balloon, it will get larger. But we have not put any more air into the balloon. And still it gets larger. Curiously enough, the air in the balloon seems to act in the same way as the water in the kettle. What do you suppose heating does to materials like water and air? You might expect that if the balloon were cooled, it would get smaller. How could you find out if this is true?

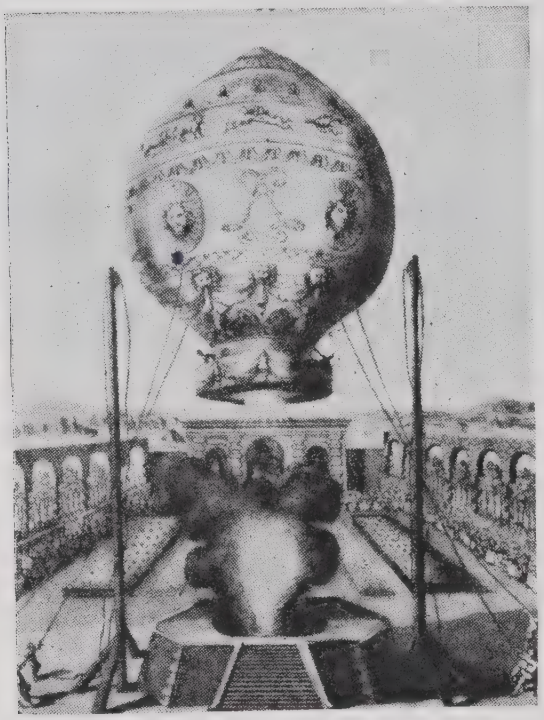


FIG. 88. The first balloon was made in 1783 by the Montgolfier brothers of France. They built a fire beneath the balloon, which filled the balloon with hot air and smoke.

One day at home a boy tried to open a bottle that had a glass stopper. He used all his strength, but he could not budge the stopper. Finally he asked his mother what to do, and she said, "Pour some hot water on the neck of the bottle." He tried this, and the stopper came out quite easily. Here again we see that heating a

material changed it in some way. How do you explain what happened?

The next time you take a hot bath, look at the window in the bathroom before and after you take your bath. Usually you will find that a thin layer of water has collected on the window. You have probably amused yourself by writing your name in this layer of water. Where did this water come from? And why did it collect on the window-pane? If the air outside is warm, usually no water will be formed on the window. Why is the film of water more likely to form on a cold day than on a warm day?

To answer the questions asked thus far in this unit, you must know how heating and cooling change materials. Keep these questions in mind as you study the unit, and answer them as soon as you can.

Problem 1:

HOW DO HEATING AND COOLING CHANGE THE SIZE OF MATERIALS?

You have just read about some everyday happenings that need to be explained. You have learned that solids, liquids, and gases take up a certain amount of space. When materials are heated, it seems that they take up more space than they did before they were heated. But before we decide to believe this, we will want to test it to see if it is true.

Experiment 6. *What Effect Do Heating and Cooling Have upon the Size of Materials?* (*a*) Attach a piece of copper or iron wire about two feet long to two iron stands or other supports (Figure 89). Hang a small weight from the center and stretch the wire as tightly as possible. Carefully mark

FIG. 89. Apparatus for Experiment 6a

the distance of the weight above the table. Now heat the wire along its whole length with a Bunsen burner or other flame. Again notice the height of the weight. Does the height change? How does the length of the hot wire compare with the length of the cold wire? Now allow the wire to cool. What happens? What is your answer to the problem you were trying to solve?

b) Fit a test-tube with a cork. Bore a hole in the cork and insert a twelve-inch piece of glass tubing of the smallest diameter you can find. Fill the test-tube with colored water or red ink. Insert the cork and tubing in the test-tube. Have enough liquid in the test-tube so that it will go up into the tubing a little way above the cork. Tie a string around the tubing at the level of the liquid (Figure 90). Heat the test-tube gently. What happens to the level of the liquid? How can you explain what happens?

Place the test-tube in a jar of cold water. What happens to the level of the liquid in the test-tube? How can you explain what happens?

c) Use the test-tube, cork, and glass tubing that you used

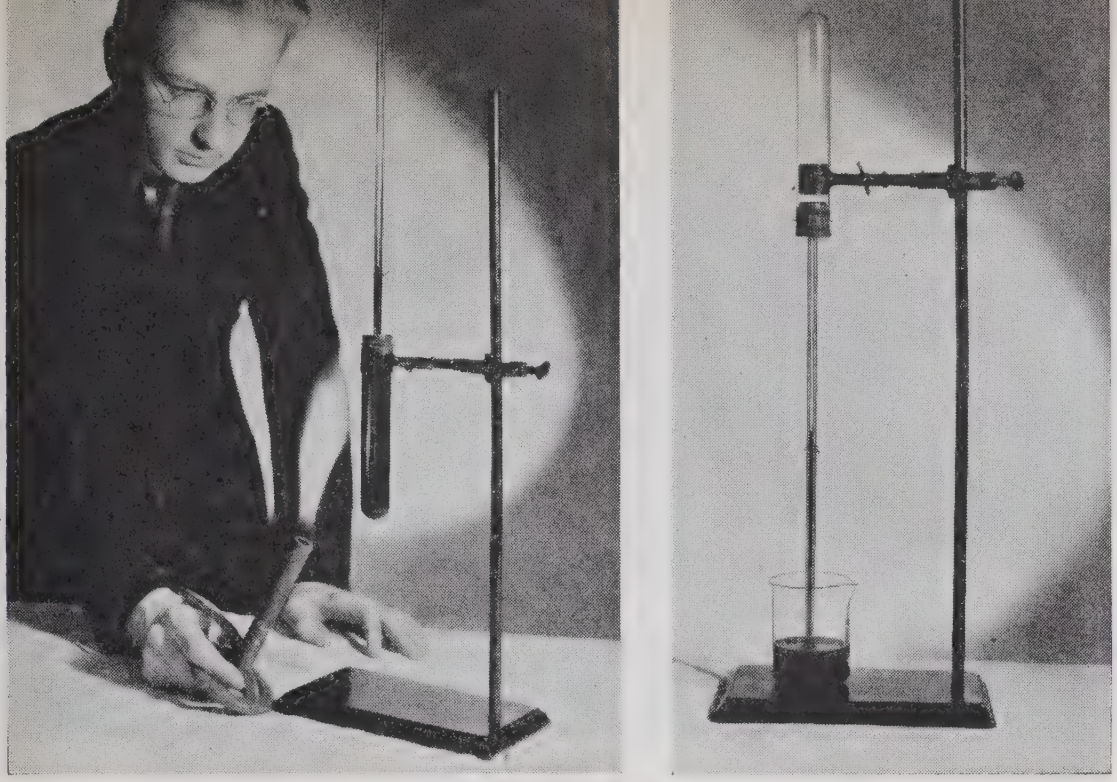


FIG. 90. Apparatus for Experiment 6b (at the left) and for Experiment 6c (at the right)

in part *b*. Have the inside of the test-tube clean and dry. Place the end of the glass tubing in some colored water (Figure 90) and heat the test-tube. Notice what happens. How do you explain this?

Allow the test-tube to cool. What happens? Pour some cold water on the test-tube. What happens? What is your conclusion?

We may tell what happened in the experiment in the following words: The wire *expanded*, or got longer, when heated; it *contracted*, or got shorter, when cooled. The water in the tube expanded when heated and contracted when cooled. The air in the test-tube also expanded when heated and contracted when cooled. If you tested other solids, liquids, and gases, you would find that they, too, expand when heated and contract when cooled.

Now we can explain why the water overflowed from the kettle when it was heated. We see, too, why the balloon got larger over the hot stove and why the glass stopper came out easily when the neck of the bottle was heated.

FIG. 91. In modern industry there are many examples of what happens when metal is heated and cooled. Here you see a locomotive tire being heated with hot gases. The heat will make it large enough to fit over the center of a wheel. When it cools, it will shrink enough in size to fit the wheel center snugly.

Materials expand when heated; that is, they get larger. They get longer, wider, and thicker.

Now before you leave this problem, you should think more about what you have learned. It is a *principle of science* that most solids expand when heated and contract when cooled. A principle of science is a statement that tells what happens under certain conditions.

Scientists discover what happens by experimenting. By experimenting you discovered what happens when a metal is heated or cooled. Of course, the scientist experiments with many different kinds of solids to see if all of them change in size when heated or cooled. Then he makes a statement to tell what he discovers. This statement is a principle of science.

Sometimes we find exceptions to the principle; that is, the principle is not true in some one case. However, there are very few exceptions to a science principle, and

we are usually safe in using the principle to explain the things we see happening.

You have learned three new science principles: Solids expand when heated and contract when cooled; liquids also expand when heated and contract when cooled; and gases expand when heated and contract when cooled. When you have learned a principle of science, you find that it may be used to explain a great many things. That is why the most important part of your science work is learning principles of science. To show you how valuable science principles are, let us examine a few things that we see happening almost every day.

If you help your mother wash the dishes, you know that you should never pour very hot water on thick glass tumblers or other thick glass dishes. If you do, the glass will usually crack. We can explain what happens by using the principle we have just learned. The hot water causes the glass to expand. If the glass is very thick, it will not get heated all the way through at once. The outer surface of the glass will become heated before the inside. The outside of the glass will thus expand faster than the inside of the glass. Something has to give way; so the glass cracks.

If you want to wash thick glass articles in hot water, the temperature must be raised gradually either by adding the hot water very slowly or by slowly heating the water over a fire. You should now be able to answer this question: Why do not thin glass tumblers break so easily when placed in very hot water?

Now let us think about a question. The question is this: Why is one end of a long iron bridge sometimes placed on rollers? At first, you might not believe that

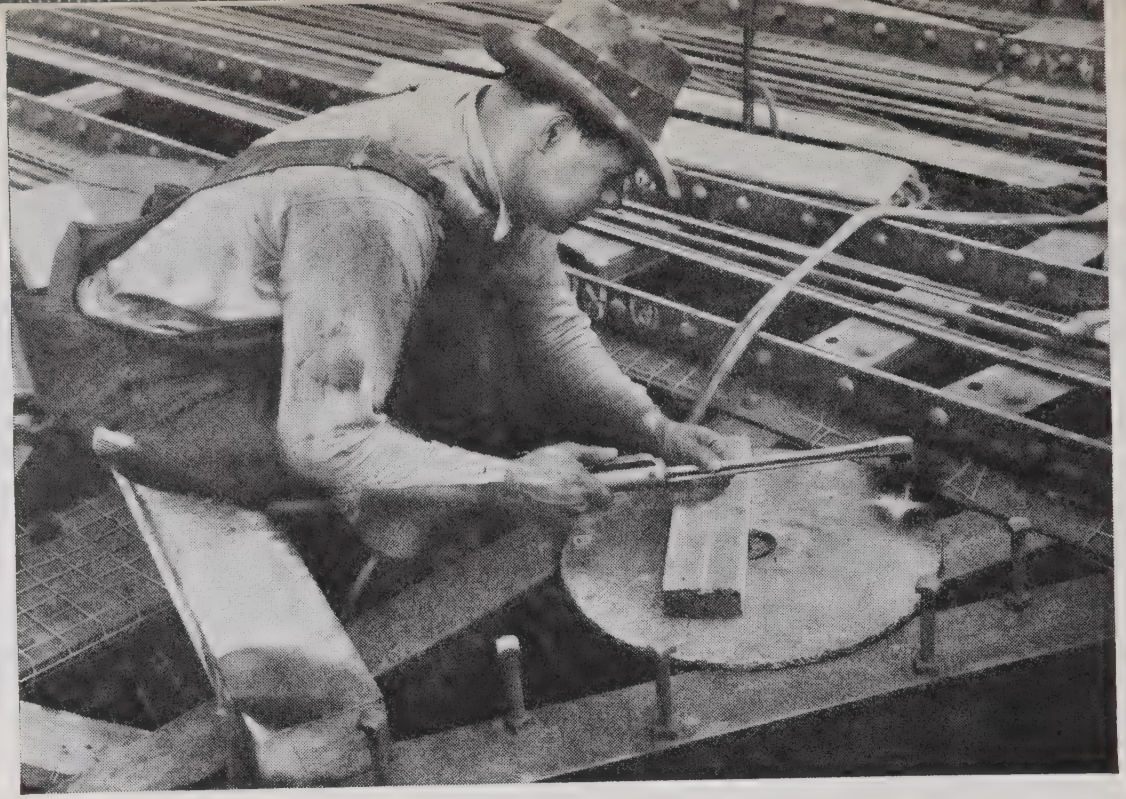


FIG. 92. This man is working on a bridge with an acetylene-gas torch. It burns with such a hot flame that it melts the steel as readily as a knife cuts butter. With it holes are cut for hot rivets. When the metal and the rivets have cooled, they will contract and be held together tightly.

this question could be answered by using our principle. We have not studied anything about bridges, but we have found out what heating and cooling do to solids. If we stop and think a minute, we will see that our principle solves this problem.

In most parts of the United States there are great changes in temperature during the year. The change in temperature from the hottest day in summer to the coldest day in winter may be as much as 100 degrees. In an iron bridge 1000 feet long, this change of 100 degrees will make a difference of over five inches in the length of the bridge. You see now why one end must be free to move—why it must be placed on rollers. Some method must be used to allow room for the expansion and contraction of the iron; otherwise, the iron would bend or break.

For many years you have been using a thermometer to tell you how hot or cold it is. You see the mercury or colored liquid go down, and you know that the air is getting colder. You see the liquid rise, and you know that it is getting warmer. Of course, what happens is that the mercury in the bulb expands when heated and forces mercury up in the tube. When the air gets colder, the mercury in the bulb contracts, and the mercury in the tube falls back.

Here is another everyday happening that we can explain when we know how heat affects liquids. To keep your automobile engine from becoming overheated, you try to have the radiator nearly full of water. Usually the water is cold when you pour it in. If you fill the radiator until it is level, and then drive the car until the water gets very hot, you will find that water is coming out on the hood or pouring out from a pipe beneath the car. Perhaps you have noticed the directions on a can of anti-freeze solution used in automobile radiators. The directions say, "Do *not* fill the radiator entirely full of water. If you do, some of the anti-freeze solution will be lost as you drive." You can see now the reason for these directions.

When your mother makes an angel food cake, she beats the whites of many

FIG. 93. A mother and her daughter are busy canning peas. If they filled the jars entirely full of peas and cold water, covered them tightly, and then placed them in a steam cooker, what would probably happen?

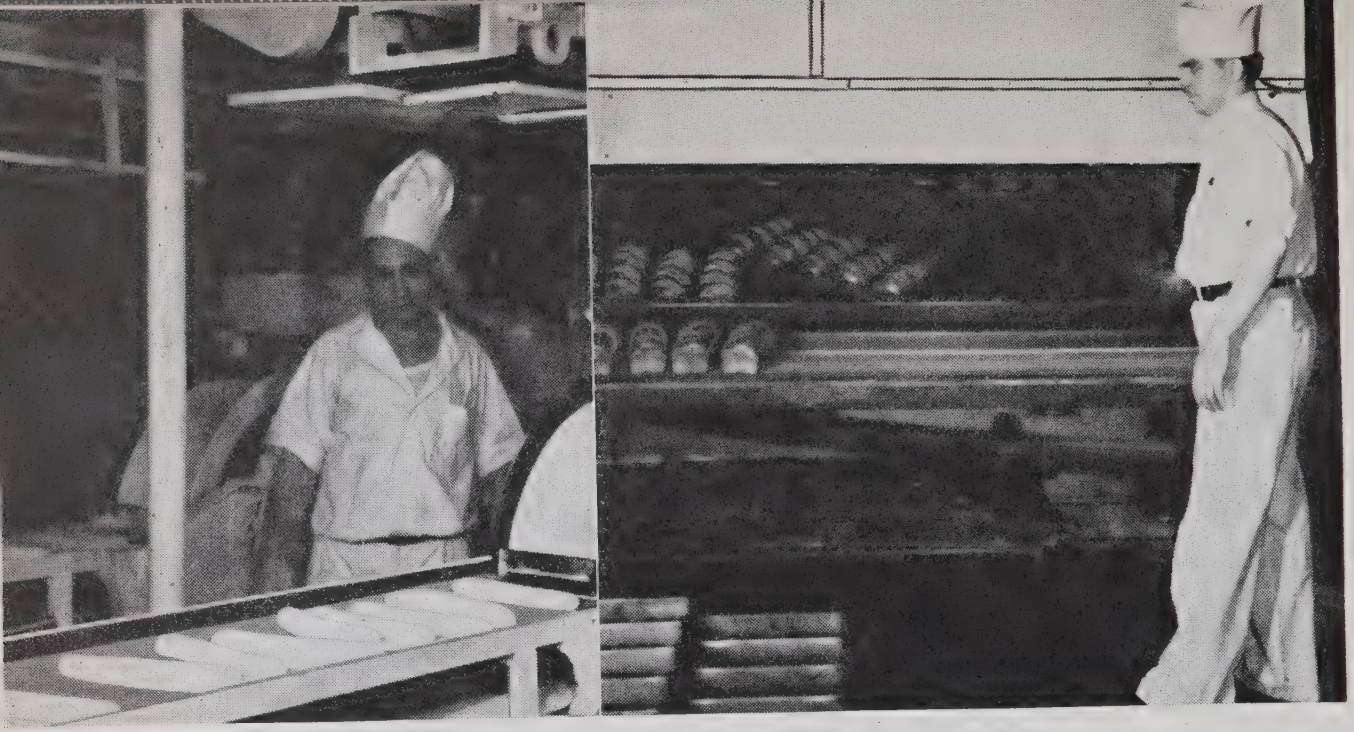


FIG. 94. These two scenes in a large bakery show you how loaves of bread look before and after baking. The dough is full of gas made by the yeast in it. When the dough is placed in a hot oven, the gas expands and makes the loaves of bread large and light.

eggs. Beating the eggs traps air in them, and the beaten eggs become fluffy and white. Then the eggs are mixed with the flour and other materials and placed in the oven. Now why does this wet mass of material swell up into a light, tasty cake? You know a science principle that will tell you. The air in the beaten eggs and the gas from the baking powder expand when heated in the oven, and the cake "rises." When you cut the cake, you can see the holes made in it by the expanding air bubbles.

If you have taken an automobile trip on a hot day in summer, you may have seen your father let some air out of the tires. Why did he do this? When you drive over a hot concrete road, the tires get very hot, and the air inside expands. Since the air cannot get out of the tires, it pushes against the walls of the tires with greater force. If the tires are blown up very tight to begin with, the extra pressure caused by the heat may burst them.

Science principles, as you see, may be used to explain many things that we see happening every day. Really to understand a principle, you must practice using it to explain the things going on around you. At the end of each problem and at the end of the unit you will find a list of things to explain. You will see how valuable a principle is in learning to understand the world in which you live.

Self-Testing Exercises

1. Copy the sentences below. Complete each sentence with the word that will make it a true statement.

a) When solids get larger, we say that they .....

b) When solids get smaller, we say that they .....

c) Solids ..... when heated.

d) Solids ..... when cooled.

e) Liquids ..... when heated.

f) Liquids ..... when cooled.

g) Gases ..... when heated.

h) Gases ..... when cooled.

2. What does a principle of science tell us?

3. How do scientists discover principles of science?

Problems to Solve

1. Men employed by a telephone company are stringing wire between poles on a hot summer day. Should they allow a little slack in the wire, or should they stretch it as tightly as possible? Explain.

2. The metal cover of a fruit jar can often be loosened if hot water is poured on the metal. Explain.

3. When fruit is canned, the glass jar is usually filled to the top with very hot fruit and syrup. But when the jar is examined later on, it is found to be no longer full. Explain.

FIG. 95. This concrete pavement will never crack like that in Figure 87. It is laid in blocks, and the spaces between these blocks are filled with a material made of cane fiber. This material will squeeze together when the heat expands the concrete and spread out again when the concrete contracts.

4. A man who lived in a part of our country where the nights are cold and the days very hot filled the tank of his car with gasoline on a very cold night and let the car stand outdoors all the next day. Was he unwise in what he did? Explain.

5. Figure 87 shows what happened to one concrete road on a very hot day. Why do you think this happened?

6. If a fountain-pen is filled with ink and carried on a very hot day, it will sometimes leak. Explain.

7. A football is pumped up in a warm room and is then used outdoors, where the temperature is about freezing. Will it become softer or harder when it is taken outdoors? Explain.

8. A milk bottle with only a little milk in it was taken from a very cold refrigerator and placed on a kitchen table. Soon there was a "fizzing" sound, and bubbles began to come out around the paper cap of the bottle. Explain why.

9. Explain how you might make a thermometer using air instead of mercury. (Refer to Experiment 6.)

10. In the exercises above you have seen that many different things are explained by the principles you have learned. Try to find some other everyday happenings that can be explained by these principles. Write them up as exercises like the ones above and see whether your classmates can explain them.

Problem 2:

WHAT EFFECT DOES HEATING HAVE UPON THE STATE OF MATTER?

HOW ARE SOLIDS CHANGED TO LIQUIDS? You have been using the word "material" to mean anything that takes up space and has weight. Scientists use another word to mean the same thing. They use the word *matter*. You have seen that matter, or a material, may be in the form of a solid, a liquid, or a gas. Scientists call these the *states* of matter; that is, matter may be in a solid state, a liquid state, or a gaseous state. You are now going to find out how heating may change matter from one state to another.

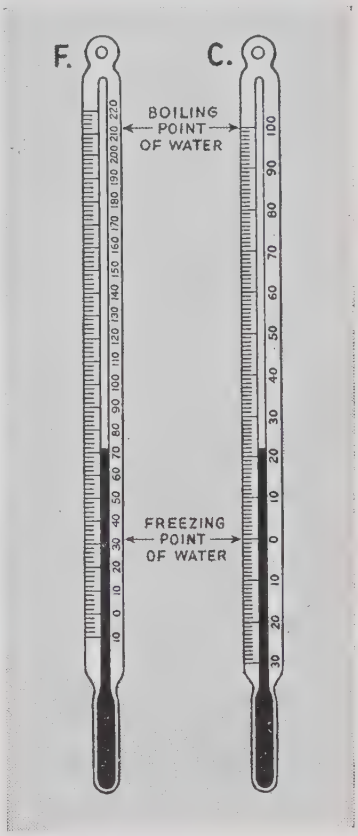


FIG. 96. Centigrade and Fahrenheit thermometers

First, we want to understand these terms: freezing point, melting point, and boiling point. The *freezing point* of water is the temperature at which it freezes, or changes from liquid to solid. This same temperature is the *melting point* of ice. The *boiling point* of water is the temperature at which it boils.

The temperature for the freezing point and the boiling point of water differs on the two kinds of thermometers, the *Fahrenheit* (F.) and the *centigrade* (C.) On the Fahrenheit thermometer—the kind in your home or school-room—the freezing point is 32°, and the boiling point is 212°. The distance between the two points

is divided into 180 degrees. On the centigrade thermometer, which scientists use a great deal in their work, the freezing point is 0°, and the boiling point is 100°. The distance between the two points is then divided into 100 equal parts.

If a cake of ice, or water in a solid state, is brought into a warm room, it melts. In other words, it changes to a liquid. Water can exist as ice only when the temperature is below freezing. If the air is warmer than this, some of the heat from the air is taken up by the ice, and the ice melts. You can see this take place if you add some ice to a glass of water. The water will get much colder, and the ice will melt. The heat from the water melts the ice.

Many other solids are changed to liquids, too, if they are heated enough. We do not see them in a liquid state very often, because they are seldom heated enough to make them melt. If you will look at Table 2, you will find the melting point of some of our common metals. This table tells you just how hot these metals must get before they change from solids to liquids.

TABLE 2. Melting Points of Some Common Metals

Metals	Degrees Fahrenheit	Degrees centigrade
Wood's metal*	158	70
Tin	450	231.9
Lead	621	327
Zinc	787	419.4
Aluminum	1218	658.7
Silver	1761	960.5
Gold	1945	1063
Copper	1981	1083
Platinum	3191	1755

*A mixture made of tin, lead, and other metals.

Some substances do not have a definite temperature at which they suddenly melt or freeze. Butter, for example, is hard when it is cold. As it is warmed, it becomes softer and softer and finally changes to a liquid if the temperature becomes high enough. Sealing-wax and glass are two other substances that change gradually from a solid to a liquid. Glass is easily shaped because it becomes softer and softer as it is heated instead of changing suddenly from a solid to a liquid. Usually it is heated until it is red hot. At this temperature it can easily be shaped by blowing air into it, by pressing it, or by bending it.

FIG. 97. This worker is an experienced glassblower in a large glass works. He is blowing a ball of hot glass into a mold. It will come out of this mold as a red lantern globe to be used as a railroad signal.

In thousands of factories and mills throughout the world men are using heat to change solids to liquids. Copper, iron, lead, aluminum, glass, and many other solid materials are melted and poured into molds to make parts for our roller-skates, bicycles, fountain-pens, automobiles, airplanes, cooking utensils, furnaces, tools, and the countless other things we use.

From what you have just read you can easily see why scientists have spent many years studying and experimenting to solve the problem, "What does heat do to materials?" One of the things they needed to find out was how to get higher temperatures. The sun would give only about 125 degrees at its hottest. An open fire of wood, coal, or charcoal would give a temperature of about 750 degrees. Such temperatures were not hot enough to melt iron and other metals.

Men needed higher temperatures than those, and they found out how to get them. In the great furnaces used to melt iron and steel, the temperatures are over three thousand degrees. Our modern steam boilers have devices called *super-heaters* that have been invented to make the steam hotter than it is when it comes out of the boiling water. Men have learned to get high temperatures because they needed the heat to change materials in ways that were useful to them.

HOW ARE LIQUIDS CHANGED TO GASES? After a rain the little puddles of water on the pavements and sidewalks disappear in a few hours. Wet clothes hung out on the line soon dry. Water left in an open pan finally disappears. We see these things happen so often that we pay little attention to them. Do you ever wonder what becomes of the water? It might soak into the pavement or drip from the wet clothes. Some of it does. But you know that water cannot soak through a glass tumbler or an aluminum pan. We say that the water "dries up." And we know that it has changed to a gas and mixed with the air. Before you finish this unit, you will see by an experiment that there really is water in the air.

Scientists have a word to describe the changing of a liquid to a gas; the word is *evaporation*. You can say that a liquid changes to a gas, or you can say that a liquid *evaporates*. And one of the problems that scientists have studied is that of finding how and why liquids evaporate. You can do an experiment that will show you an important principle of evaporation.

EXPERIMENT 7. *Does Heating Make Water Evaporate More Quickly?* Dip a dish, bottle, or glass tumbler into some cold water. Dip another dish into some very hot water. Find out which dish dries the quicker. Does heating speed up or slow down the rate of evaporation?

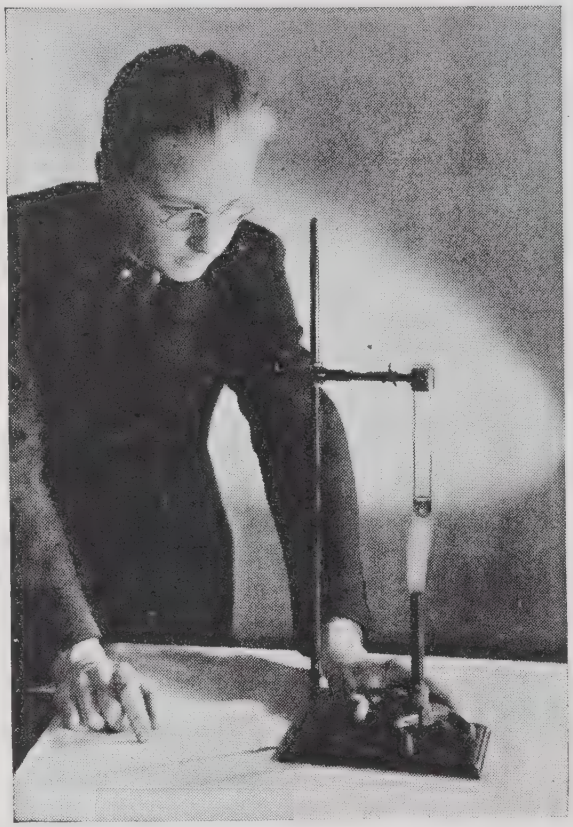


FIG. 98. This boy is experimenting to see whether a small amount of water in a test-tube will evaporate faster when the heat is directly beneath it or is farther away.

Water is always changing from a liquid to a gas at any temperature, that is, no matter how hot or how cold it is. But the experiment has shown you that the speed at which it changes to a gas depends upon its temperature. The hotter the water is, the faster it changes. The colder it is, the slower it changes.

In Experiment 7 you used water as an example of a liquid. Perhaps you wonder if other liquids also evapo-

rate. Yes, they do, but they do not change at the same speed as water. Gasoline, for example, evaporates much more quickly than water. You can prove this. Measure out equal amounts of gasoline and water and pour each into a separate saucer of exactly the same size and shape. Then notice which one disappears first. (*Caution:* As gasoline is easily set on fire, keep it away from a flame.) Ether, a drug used to put a person to sleep during an operation, evaporates much more quickly than gasoline. If a small quantity of ether is poured on the hand, the liquid will disappear almost instantly. Heavy, thick liquids, such as oil, evaporate more slowly than water. Different liquids evaporate at different speeds.

Now let us see what we have learned about evaporation: (1) Liquids change to gases, that is, evaporate, at all temperatures. (2) Heat increases the speed of evaporation. (3) Different liquids evaporate at different rates.

We can use these ideas about evaporation to explain many changes that take place every day in the world around us. Perhaps you have noticed that the grass is covered with dew in the early morning on a summer day. Shortly after the sun rises, the dew disappears. What has become of it? We can answer this question by remembering what we have learned. Because it is cool in the early morning, evaporation takes place very slowly; but when the sun comes up, the grass and dew are warmed, and the speed of evaporation is increased. The dew soon disappears into the air.

Perhaps you have cleaned grease from your clothing by rubbing the spot with gasoline. You have seen that the spot dries almost immediately—much more quickly than a spot of water dries. What we have learned tells

us that we are using a liquid that evaporates very quickly; so the spot is soon dry.

If water or any other liquid is heated hot enough, it will boil. When a liquid boils, bubbles of gas are produced in the liquid. These bubbles rise to the surface and break. The gas passes off into the air. Strangely enough, in a pan that is open to the air, a liquid cannot be heated any hotter than its boiling point. If boiling water is heated more, it merely boils faster. Its temperature stays the same.

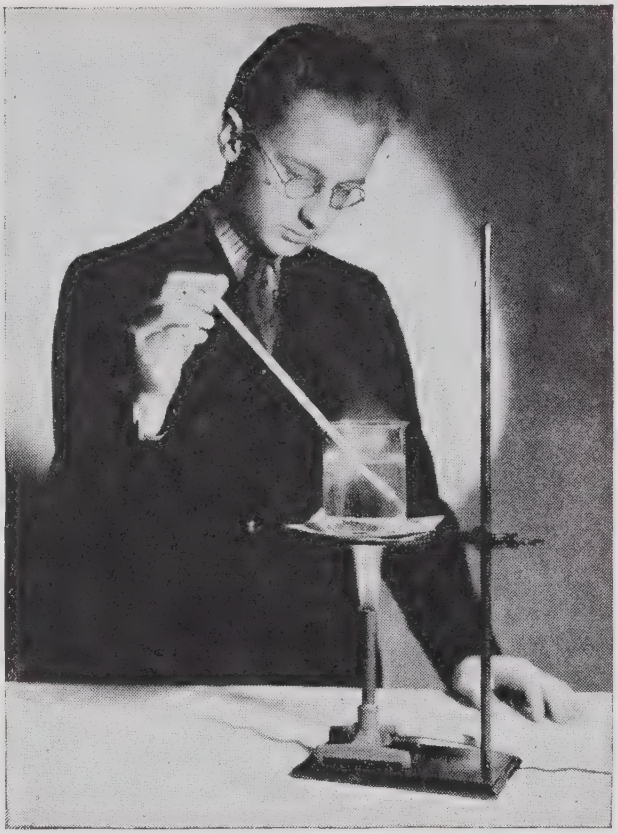


FIG. 99. By reading the thermometer in the beaker this student is finding out for himself the temperature of boiling water.

In an open pan or dish a liquid can be heated only up to the point where it begins to boil. Table 3 gives the boiling points of some common liquids. From what the

TABLE 3. BOILING POINTS OF SOME COMMON LIQUIDS

Liquid	Degrees Fahrenheit	Degrees centigrade
Ether	93	34
Carbona	171	77
Alcohol	172	78
Water	212	100
Turpentine	318	159
Glycerine	556	291
Mercury	675	357

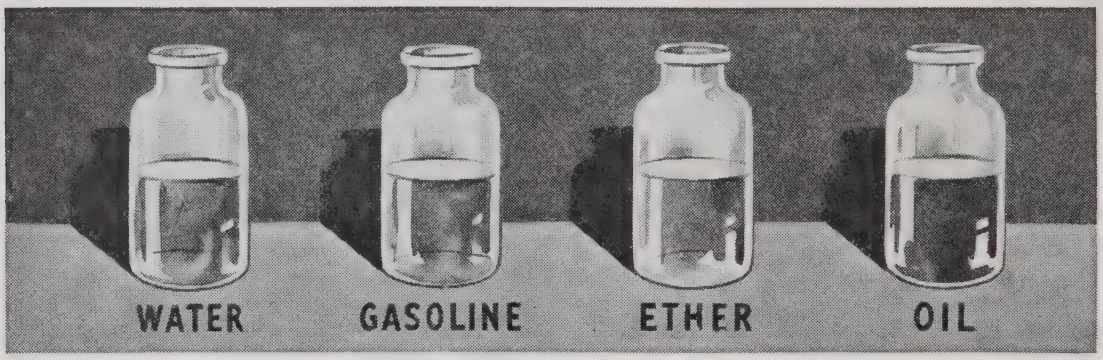


FIG. 100. Which liquid will evaporate first?

table tells you, see if you can explain why alcohol disappears from the radiator of an automobile quicker than water disappears. Would a mixture of water and glycerine boil more quickly or less quickly than water?

Self-Testing Exercises

1. Copy the sentences below, and put the correct word or words in each blank space.

a) Water disappears when placed in an open saucer. It changes from a ..... to a .....

b) Evaporation is the process in which a ..... changes to a .....

c) Liquids are (*sometimes*) (*always*) ..... evaporating.

d) Different liquids evaporate (*at the same rate*) (*at different rates*) .....

e) Windows dry after a rain because (*the water all runs off*) (*some of the water runs off and some of it evaporates*) .....

f) Evaporation usually takes place more rapidly (*at night*) (*during the daytime*) .....

g) The surface of the soil is usually drier than the soil a few inches under the surface. The explanation for this is that (*the water sinks into the soil*) (*the water on the surface evaporates*) .....

h) Evaporation will usually take place more rapidly on a warm day than on a cold day. Is this true or false? .....

i) Water boils at ..... degrees Fahrenheit.
j) Water boils at ..... degrees centigrade.
k) When water is boiling, bubbles of ..... form.
l) If more heat is applied when the water is boiling, the water will boil ..... The temperature will be (*higher*) (*lower*) (*the same*) .....
m) There are three states of matter: ....., ..., and .....

2. How is a solid changed to a liquid?
3. How do we use heat to make things?

Problems to Solve

1. Why must a person add more water to the radiator of an automobile if he is taking a long trip at a high speed than if he is driving slowly for a short distance?

2. Why do candies like fudge or nougat become very hard and dry if they are exposed to the air for some time? How might you prevent this?

3. Why should you always screw on tightly the lid of a bottle of paste?

4. Pop-corn kernels contain a great deal of water. When they are heated, they pop. What is a probable explanation for the "popping"?

5. If you are boiling potatoes, how should the gas be regulated so as to cook the potatoes in the shortest possible time with the least amount of fuel? Explain your answer.

6. Does the chocolate used in chocolate bars have a definite melting point? Give reasons for your answer.

7. On hot days asphalt pavements will show the marks of heels. Explain.

8. Why cannot a solid like ice be shaped by pounding, as copper or iron is shaped?

9. Suppose that butter had a definite melting point just as ice has. How would this affect our ways of using butter?

Problem 3:

WHAT HAPPENS TO MATERIALS WHEN THEY ARE COOLED?

HOW DOES COOLING AFFECT GASES? Before you read the study material that follows, you might try to *predict* what happens to gases and liquids when they are cooled. "To predict" means to tell what you think will happen before it has happened.

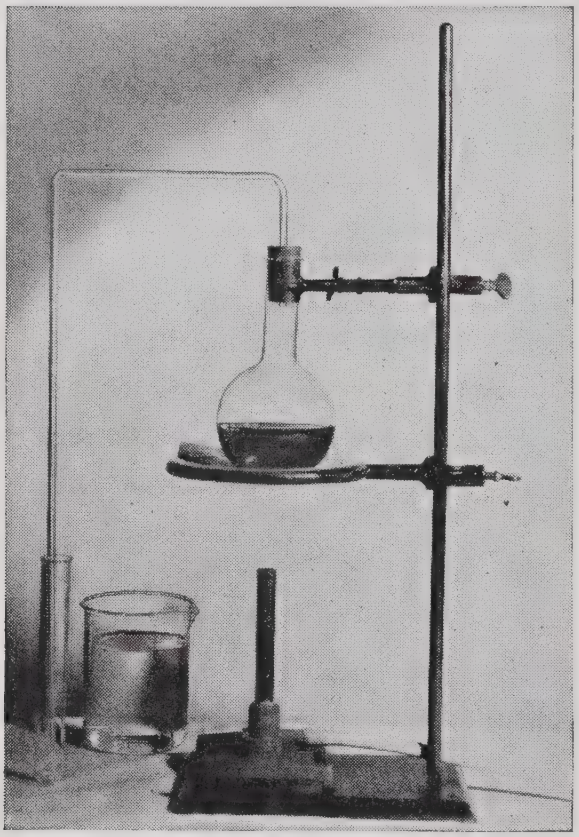


FIG. 101. Experiment 8

A scientist is always trying to predict what will happen. He observes something happen, and he notices carefully the conditions under which it happens. Then he uses what he has learned to predict what will happen in other situations like the one he has observed. For example, you have already seen that you can change solids to liquids and liquids to gases by heating them. Now what do you suppose will happen if you cool a gas or a liquid, that is, if you take heat away from it?

When water boils, it changes to *steam*. You probably think that you have seen steam, but you never have seen it, because steam is an invisible gas. You will soon learn what it is that you call steam. Let us arrange an experiment in which we collect some steam and then cool it.

EXPERIMENT 8. *What Happens to Steam When It Is Cooled?* First we will make some steam by heating water in a flask. To keep the steam from being lost in the air, we will use a stopper with a glass delivery tube in it (Figure 101). Then we will place a test-tube under the delivery tube and pass the steam into the test-tube. Can you see the steam? Does the steam change to a liquid? Now place the test-tube in a beaker of cold water and pass the steam into the tube. Does it change to a liquid now? Was your prediction correct?

FIG. 102. What is the reason for the space between the spout and the white cloud?

You remember that water boils when it is heated to 212° Fahrenheit or 100° centigrade. As it boils, it turns into bubbles of steam that pass into the air. When this steam is cooled below 212° Fahrenheit, it *condenses.* Now we can explain the white cloud that appears above the spout of a tea-kettle of boiling water. As the steam comes from the spout, you cannot see it. A short distance from the spout, the steam strikes the cool air around the kettle. The steam is cooled and condenses into tiny drops of water. The white cloud is made of millions of tiny drops of water floating in the air. You have seen steam condense around the smoke-stack of a locomotive. Some people call the white cloud steam. Are they correct?

In Experiment 8 the water in the test-tube was *distilled* water, and the way you made it is called the process of *distillation.* To get distilled water, the water is boiled until it is all changed to steam; then the steam is changed

back to water, or, as a scientist would say, the steam is cooled and condensed. Other liquids can be distilled in the same way.

Later on in your science study you will learn why the process of distillation is so useful to us. But let us see now one way in which distillation is used. Ocean water, as you know, is so salty and bitter that it cannot be used for drinking. Ocean liners ordinarily carry enough fresh water for the voyage. But in case they run out of fresh water, they distil ocean water. Try the following experiment, and you can see what happens.

Experiment 9. *What Happens When Water Is Distilled?* Dissolve some salt in water so that the water tastes very strongly of salt. Then distil the water. Taste the distilled water. Is it salty?

When water changes to steam, the solid materials dissolved in the water do not change into gases. They remain in the pan or other vessel in which the water was boiled. This science principle is very useful to us in many ways, as you will learn later.

Other gases may be changed to liquids, too, if they are cooled enough. Even air can be changed to a liquid that looks like water. To do this, the air has to be cooled to a temperature of more than 200° below zero Fahrenheit. If you place a glass of liquid air on the table, it will immediately begin to boil and will quickly disappear. In order to remain a liquid, it must be kept at a temperature of 190° below zero centigrade.

Have you ever noticed that drops of water sometimes collect on the windows inside of the house? Sometimes these drops are very small and merely form a film over

FIG. 103. Because the air at the top of the mountain is below freezing temperature, some of the water vapor comes out of the air as snow. The air in the valley is warmer and can hold more water vapor. When water vapor comes out of this air, it falls as rain.

the glass. But you can see that the film is water if you run your finger through it. Where does this water come from? And why does it form on the glass?

You have already learned that water is constantly changing to a gas and mixing with the air. Air can hold only a certain amount of water vapor at a certain temperature. Hot air can hold a great deal of water vapor; cold air can hold much less. Now let us suppose that water has been evaporating into the air, and that the air has taken up all the water vapor it can hold. What do you suppose will happen if the air is cooled? Some of the water vapor will have to come out of the air. When it comes out of the air, it condenses into liquid water. Water on the window-pane is formed in this way. The air in the room contains a great deal of water vapor. The window-pane gets cold, and it cools the air that comes in contact with it. The result is that some of the water vapor condenses on the glass.

FIG. 104. Washington, D. C., looked like this one morning in a heavy fog. Fog forms for the same reason that moisture formed on the cup in Experiment 10. The air near the ground is cooled. Some of the water vapor condenses, and a cloud is formed near the earth.

You might like to try an experiment in which you make some water vapor condense from the air.

EXPERIMENT 10. *How Can Water Vapor from the Air Be Condensed?* Obtain a bright tin cup. Fill it half full of cold water. Watch the outside of the cup. Do you see a film of moisture forming on it? If not, add a little ice and stir the mixture of ice and water. Keep on adding ice until a film of moisture appears. It may be necessary to add salt, also, to make the ice melt more rapidly.

If the air has a large amount of water vapor in it, it need be cooled only a few degrees to cause condensation to take place. If only a small amount of water vapor is present, the air must be cooled many degrees before condensation takes place. You have probably blown your breath on a cold window-pane to see the film of water collect on the glass. Do you think that your breath contains a large amount of water vapor or a small amount? Later you will learn how the condensation of water vapor in the air forms clouds, rain, and dew.

HOW DOES COOLING AFFECT LIQUIDS? You have seen many examples of what happens to liquids when they are cooled. Liquid water changes to ice at 32° Fahrenheit or 0° centigrade. Our mothers often cover glasses of jelly by pouring a layer of hot liquid paraffin over them. The liquid paraffin soon changes into solid paraffin and keeps the jelly from spoiling. The wax at the top of a candle melts while the candle burns. Soon after the candle is put out, the liquid wax becomes solid again. Lard is melted to fry doughnuts and potatoes. After the pan is set aside and allowed to cool, the melted lard changes into a solid again. Lead is melted and poured into molds to make toy soldiers. When it cools, it hardens again.

Every liquid can be changed to a solid if it is cooled enough. Some liquids need to be cooled a great deal. Such a liquid as alcohol has to be cooled to nearly 200° below zero Fahrenheit to freeze it. Mercury can be changed to a solid if it is cooled to about 38° below zero Fahrenheit. A very interesting experiment can be performed by pouring some liquid air on mercury. Liquid air has a temperature of more than 200° below zero Fahrenheit. The mercury freezes into such a hard lump that it can be used to drive a nail.

Self-Testing Exercises

Copy the sentences below, and put the correct word or words in each blank space.

a) If a liquid is heated enough, it changes to a .....

b) To change a gas to a liquid, the gas is .....

c) The white cloud around the spout of a tea-kettle of boiling water is made of (*steam*) (*tiny drops of liquid water*) .....

d) Cold air can hold (*more*) (*less*) ..... water vapor than hot air.

e) Water vapor will condense from air if the air is (*cooled*) (*warmed*) ..... enough.

f) If air has a large amount of water vapor in it, it must be cooled (*more*) (*less*) ..... than if it contains only a small amount of water vapor.

g) Liquids change to solids when they are (*warmed*) (*cooled*) ..... enough.

h) The temperature at which liquids change to solids is (*the same*) (*different*) ..... in different liquids.

Problems to Solve

1. Most of our rain comes from water that was once in the salty ocean. Rain, however, is not salty. Explain why there is no salt in rain water.

2. When a person wearing glasses comes into a warm room from the cold outdoors, a film of moisture often forms on the glasses. Explain.

3. On very cold days we often "see our breath." What is it that we actually see?

4. When a pitcher of ice water is brought into a warm room in the summer, drops of water usually form on the pitcher. Explain.

5. In Experiment 8 you changed water into steam and then changed the steam back into a liquid. Suppose that you used muddy water in the flask. Would the water produced by condensing the steam also be muddy? How could you prove your answer? What use might we make of this?

6. Several examples were given in your text showing how we sometimes change solids to liquids when we want to use them. State some other examples.

7. Look around you at home and find examples of things that were made by changing a solid to a liquid and then allowing the liquid to change back to a solid.

Problem 4 (Optional):

HOW CAN WE EXPLAIN HOW HEAT AFFECTS MATTER?

HOW DOES THE MOLECULAR THEORY EXPLAIN CHANGE OF STATE? Do you remember the molecular theory —the theory that everything is made of tiny bits of matter called molecules? Do you remember also that these tiny bits of matter are constantly moving and that there are spaces between them? Now let us see whether this theory will explain why solids, liquids, and gases get larger when they are heated. If the theory is a good one, it ought to tell us why matter acts the way it does when it is heated.

Scientists have actually been able to prove that the molecules of a material move faster when the material is heated. The theory is that as they move faster, they bump into each other harder. Therefore they knock each other farther apart. Of course, when this happens, the material expands. When the material is cooled, the molecules move more slowly, get closer together, and the material contracts. Perhaps this will be clearer to you if you imagine a swarm of bees all bunched on a limb. They are crawling slowly over each other in an almost solid mass. You come up and make them angry. They begin to fly round and round, faster and faster. To do this, they need room, and the swarm spreads out until it is many feet across.

Do you see now how matter gets larger when it is heated, because the molecules move farther apart? And it becomes smaller when it is cooled, because the molecules slow down and get closer together.

We can also explain how heating changes materials from one state to another. When solids are heated, the

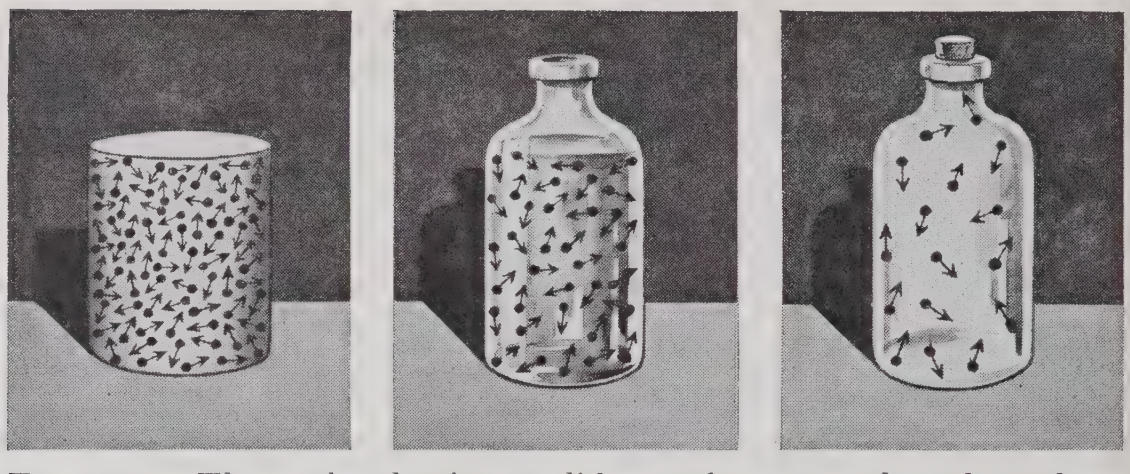


FIG. 105. The molecules in a solid are closer together than those in a liquid. And the molecules in a liquid are closer together than those in a gas.

speed of the molecules is increased. The molecules knock each other farther apart, and the solid changes to a liquid. When a liquid is heated, the molecules move still faster and knock each other still farther apart, and the liquid changes to a gas. When gases are cooled, the molecules move closer together, and gas changes to a liquid. When a liquid is cooled, the molecules move still closer together, and the liquid changes to a solid.

HOW DOES THE MOLECULAR THEORY EXPLAIN EVAPORATION? It is much easier to understand how evaporation of liquids takes place if we use the molecular theory. We found, you remember, (1) that evaporation takes place at all times, (2) that the speed of evaporation is increased by heating the liquid, (3) that liquids can be heated only to a certain temperature in an open vessel. These are all facts that we have observed in experiments. Now let us see if we can explain these facts by the molecular theory. Scientists could not explain what happens when materials are heated and cooled until they had worked out the molecular theory.

You remember that the molecules of a liquid are moving at high speed. If you could see the molecules in a dish of water, you would see billions of tiny particles darting in all directions. There are so many of them that collisions are constantly taking place. Occasionally a molecule that is moving up toward the surface of the water manages to escape a collision, and, because it is going so fast, it shoots out into the air. This is what happens when a liquid evaporates. The molecules simply escape from the liquid and fly off into the air or the surrounding space.

When the liquid is heated, the molecules move faster. The result is that more molecules fly out into the air. This, of course, means that the water evaporates more rapidly when it is heated. And this is exactly what we found in our experiment.

To explain how boiling takes place is a little more difficult. You will remember that the molecules of a liquid knock each other farther apart when the liquid is heated. The hotter the liquid gets, the harder the molecules hit each other and the farther they knock each other apart.

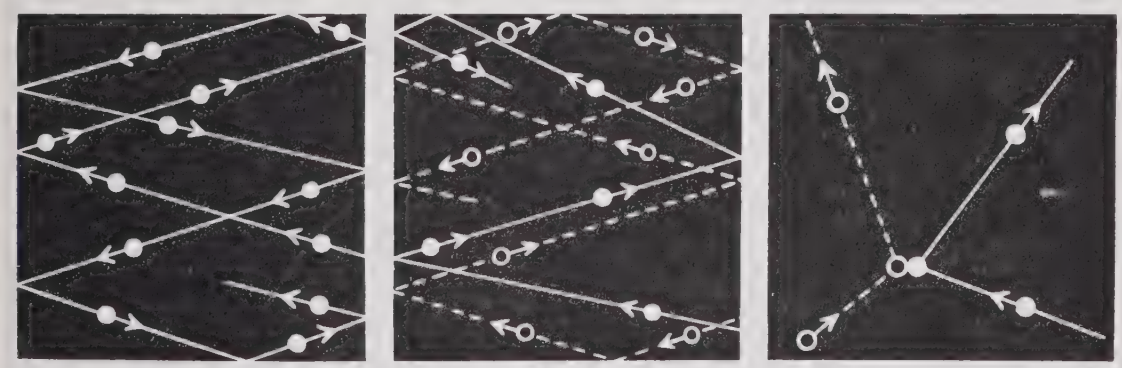


FIG. 106. The solid line in the first diagram is the path of one molecule. The second diagram shows the paths of two molecules. In the third diagram two molecules collide and change the direction of motion.

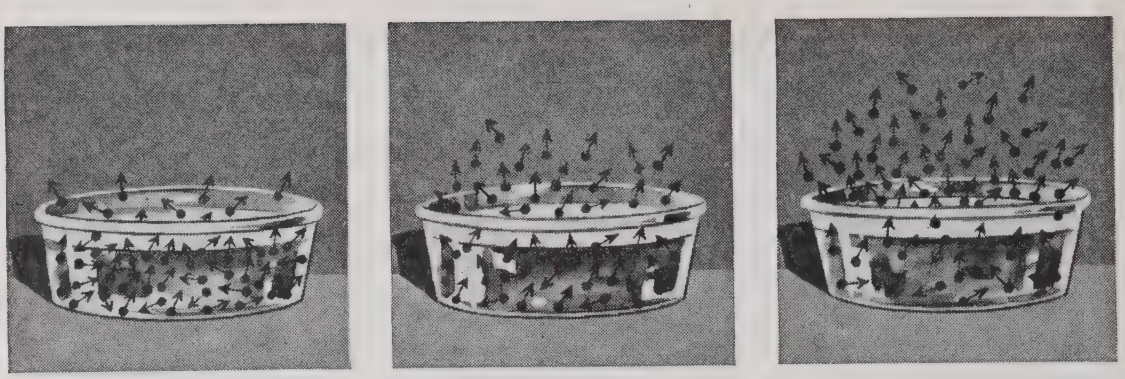


FIG. 107. From the first pan, containing water, a few molecules gradually fly off into the air. From the second pan, containing warm water, more molecules escape. When water is hot, as in the third pan, many molecules escape rapidly.

When the temperature reaches the boiling point, some of the molecules knock each other so far apart that they form a bubble of gaseous water, or steam, in the water. This bubble rises to the top of the water, and the molecules of steam mix with the air. If more heat is applied after a liquid begins to boil, more bubbles form, and the change to steam is made more rapidly. In an open pan a liquid cannot be heated higher than its boiling point because the extra heat simply changes a liquid to a gas.

Self-Testing Exercises

Copy the sentences below, and put the correct word or words in each blank space.

a) Molecules are (*closer together*) (*farther apart*) ..... in liquids than in solids.

b) Molecules are (*closer together*) (*farther apart*) ..... in gases than in liquids.

c) When gases are cooled, the molecules move (*closer together*) (*farther apart*) ....., and the gas changes to a .....

d) Evaporation takes place when a molecule ..... from the surface of a liquid.

e) At the boiling point, the space between the molecules becomes so great that some of the water is changed to a .....

f) If more heat is added after a liquid is boiling, the added heat is used to change the liquid to a ..... at a faster speed.

Problems to Solve

1. Make a drawing of a bottle of air. Use dots to represent the molecules. Now draw another bottle and show the molecules after the bottle has been heated.

2. Explain why clothes will dry faster in front of a hot stove or in the sunshine than they will in a cool place.

3. Explain what makes vapor condense from the air.

4. Are there as many molecules of water in a quart of water at a temperature of 80° F. as there are in a quart of water at 60° F.? Explain.

LOOKING BACK AT UNIT FOUR—SUMMARY EXERCISES

1. In this unit you learned that principles of science are important to you, and to all scientists, because they may be used to explain so many things that happen in the world.

Write the principles, or big ideas, of science in this unit. Make them complete sentences, like this principle that you learned in Unit Three: *All materials have weight.* You should be able to write about eight principles from Unit Four.

2. A number of important science words have been used in this unit. Be sure that you know what they mean so that you can use them intelligently. Give the meaning of each word below:

boiling point	*condense*	*distillation*	*expand*	*freezing point*
centigrade	*contract*	*evaporate*	*thermometer*	*Fahrenheit*

ADDITIONAL EXERCISES

1. In the steel framework of skyscrapers and bridges the steel beams must be riveted together. Why are the rivets heated red hot before they are inserted and hammered down?

2. Sometimes in the early morning there is a fog. (A fog is made of millions of tiny drops of water floating in the air.)

Soon the sun comes out, and in a little while all of the fog disappears. What might be the explanation for this?

3. Find out from the operator of a filling station whether his pump allows for expansion of gasoline in hot weather.

4. Gardeners say that it is much better to water the lawn and the garden after the sun has gone down than while the sun is shining. Explain.

5. If you have a medical thermometer at home, examine it and see how it differs from ordinary thermometers in its construction and in the way it works.

6. Many stoves are equipped with metal thermometers. Find out how they work. What principle of science explains how they work?

7. You can make the most important part of a metal thermometer or thermostat. Get a thin strip of brass about one quarter of an inch wide and eight inches long. Obtain a similar piece of iron or steel. Fasten them together with rivets. Heat them in the flame of a Bunsen burner. What happens? How do you explain it?

8. The temperature of your school-room is probably regulated by a thermostat. How does it operate?

9. Find out how a recording thermometer works.

10. Make a wall chart of temperatures. Get a piece of wrapping paper 8 or 10 feet long, and make a long bar on it. Start the lower end of the scale at $-273°$ C. Make a mark every $10°$ up to $1000°$ C. Place the centigrade reading above the bar. Below the bar place the Fahrenheit reading. Place interesting temperatures at the proper points along the scale, for example, boiling point of water, freezing point of water, melting point of iron or gold, temperature of the oxyhydrogen blowpipe, temperature of the human body, etc.

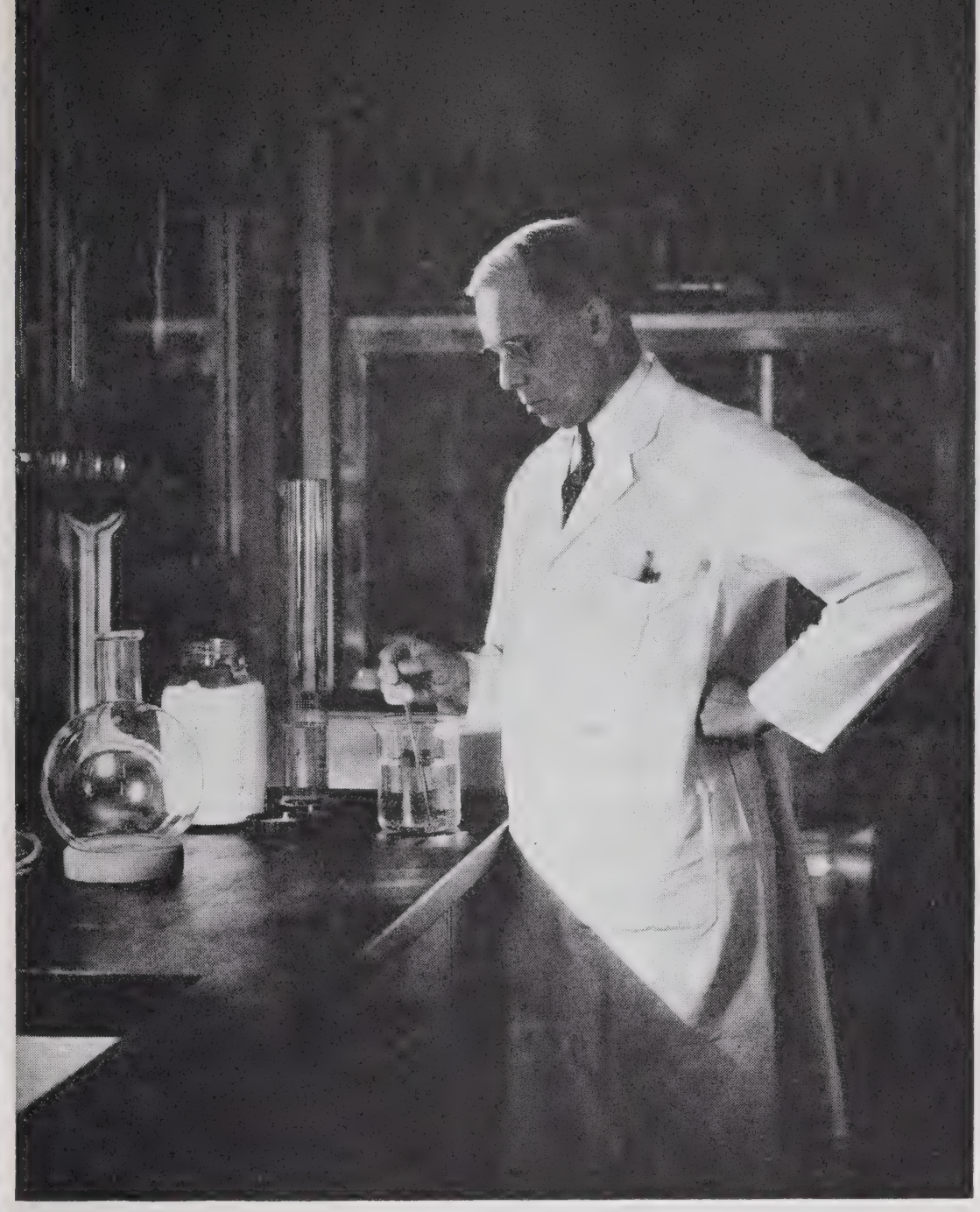


Fig. 108. Ever since the world began the materials on and in the earth have been changing. Iron has rusted; wood has burned; plants and animals have died and decayed. When men learned how to be scientists, they, too, began to make materials change. They did so because they wanted new and different materials to use. Before they could change materials, men had to discover what they are made of and what happens when they change.

UNIT FIVE

UNIT 5

HOW CAN ONE KIND OF SUBSTANCE CHANGE INTO ANOTHER KIND?

INTRODUCTORY EXERCISES

1. Houses burn, trees are blown down by the wind, and many other such changes are taking place every day. Make a list of changes that have taken place in your community within the past year.

2. In the list you made for Exercise 1, mark with an N the changes that were caused by nature. An example of such a change is the rusting of iron.

3. In your list mark with an M the changes caused by man. An example of such a change is the painting of wood to keep it from rotting.

4. List some new products that man has learned to make within the past few years because of what he has discovered about materials and their changes. *Examples:* neon gas for lighting signs, stainless steel, and Bakelite to take the place of hard rubber.

5. Make a list of as many different kinds of materials as you know.

6. Why does paint keep iron from rusting?

7. Give two examples of each of the following: element, compound, mixture.

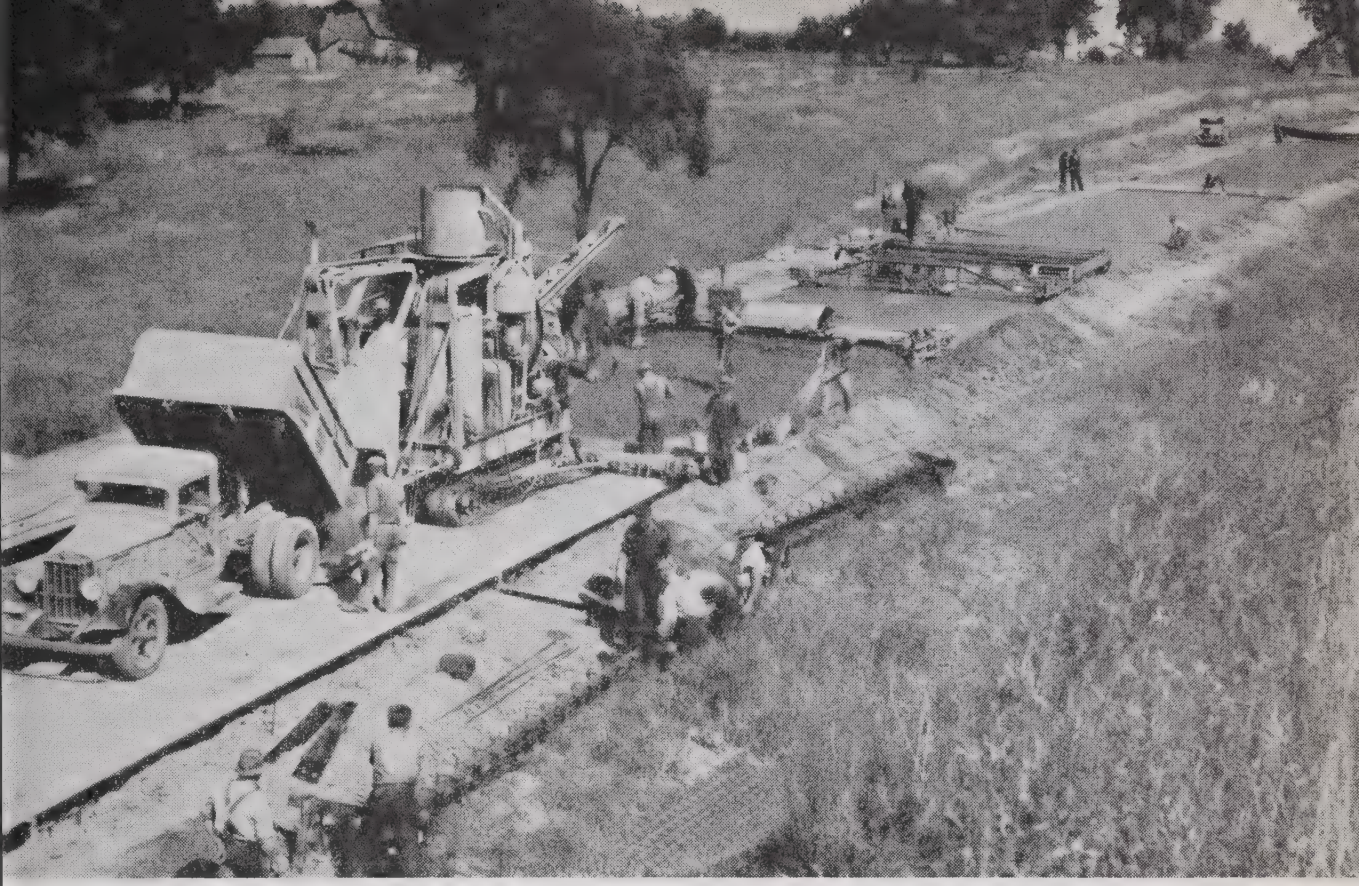


FIG. 109. Concrete for our roads and buildings is made by mixing cement with sand and gravel and then with water. But the cement, sand, gravel, and water do not just dry into concrete. Important changes in the cement and the water make a new, rock-like material out of the sand, gravel, cement, and water.

LOOKING AHEAD TO UNIT FIVE

HOW WOULD you like to be a magician? It would be fun to pick rabbits out of the air, to pull a live chicken out of an empty hat, and to make people seem to disappear. Of course we know that these are just tricks. But, to someone who does not know about science, you have been doing a few tricks, too.

You have made a wire longer simply by heating it; you have put mercury into a tube and made it tell how hot or cold things are; you have changed a liquid into an invisible gas; and you have made solid materials disappear in a glass of water. If you traveled to some unexplored place, you could probably set yourself up as a magician among the savage tribes who might be living there.

FIG. 110. The boys may be putting a fresh coat of paint on the bicycle only because they want to make the bicycle look "like new." But perhaps they also know that the coat of paint will keep the metal parts from being ruined by rusting. Do you know what change takes place when iron rusts?

But there are still more "magic tricks" that can be done with materials. So far we have not learned how to change one material into another kind of material. When we freeze liquid water, we are merely changing water from a liquid to a solid. When we change liquid water to steam, the steam is still water; it has only been changed from a liquid to a gas. When we dissolve sugar in water, we have not changed the sugar into a new material. It is still sugar. When we heat iron, it expands; when we cool it, it contracts. We have changed materials in some ways, but we have not changed them into new materials.

In this unit you are going to learn how to change a material into another kind of material. You have done this many times already. Every time you burn a piece of wood or paper, you change it into something else. When you hold a piece of paper in the flame of a match, it catches on fire and "burns up." You see a flame, some smoke, and then nothing but ashes. The paper has disappeared. It has changed into something else. Scientists say that a *chemical change* has taken place.

Chemical changes are going on around us and even in us all of the time. Many of them go on so slowly that

we never notice them. The wood of a fallen tree in the forest slowly rots and falls apart. The meat, vegetables, fruit, and candy that you eat are changed into muscle, bone, hair, and fat. Iron changes into rust, milk gets sour, and the carpet fades. All of these changes are chemical changes.

You can see that some chemical changes are helpful, and other chemical changes are harmful. When materials burn, the change gives us heat, but it may also destroy our houses. We do not like to have our iron rust or our clothing fade. However, we need the change that takes place when soft, slushy concrete changes to hard stone for our roads and buildings.

Scientists are interested in changing substances into other substances that we all need. Scientists are also interested in preventing changes in the substances that they want to keep as they are. In order to do these two things, scientists have to discover what goes on during a chemical change.

Problem 1:
WHAT ARE MATERIALS MADE OF?

WHAT ARE ELEMENTS AND COMPOUNDS? How many kinds of materials do you suppose there are? In Introductory Exercise 5 you named as many as you could. How many did you have? So far, the chemists have named over 300,000 different kinds of materials. If you could say them at the rate of eighty a minute, it would take you over sixty hours to name them all. Of course, you will not have time in this science course to study all of these materials. You will study only a few of them, but from your study you will find out many things that are true of all materials.

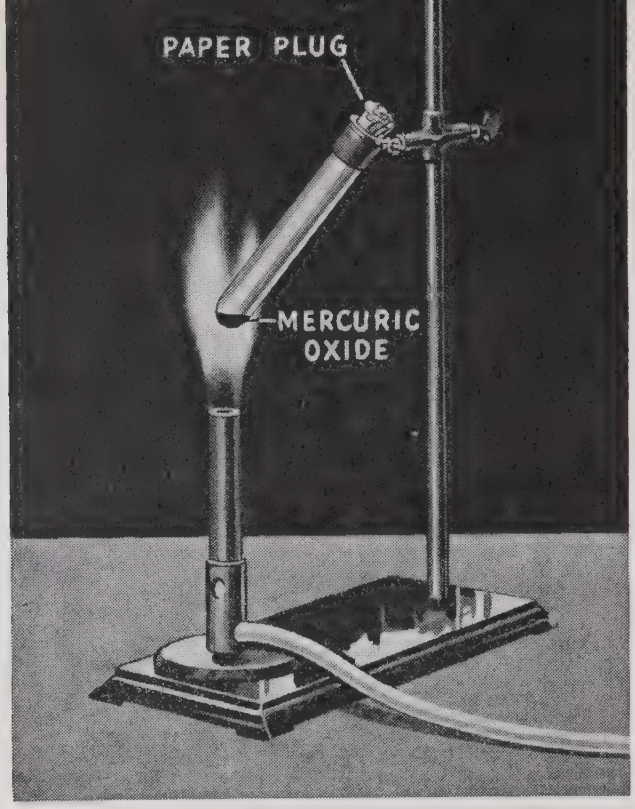


FIG. 111. Apparatus for Experiment 11

You will start your study by doing an experiment. In this experiment you will make something happen that seems to be impossible. All that you have to do is to heat a certain kind of red powder in a test-tube. This does not sound very exciting, but you will never guess what will happen. Do not expect a rabbit to jump out of the test-tube. Even a scientist cannot change a red powder into a rabbit. But he can change this powder into something else.

EXPERIMENT 11. *What Happens When Mercuric Oxide Is Heated?* First, pour a little of the mercuric-oxide powder (about enough to make a layer one-quarter inch deep) into the test-tube. Use a Pyrex or hard glass test-tube, if possible. In the mouth of the tube, put a paper plug. Then fasten the test-tube in a clamp just over the hottest part of a Bunsen-burner flame (Figure 111). After a minute or two, look at the sides of the tube about half-way to the top. What do you see? If you look closely, you will see a silvery material.

Now light a wood splinter. Let it burn a little, and then blow out the flame so that the splinter is just glowing. Remove the plug and plunge the glowing splinter into the test-tube. What happens? Notice how brightly the splinter burns.

Now heat the test-tube until all of the red powder is gone. Then scrape some of the silvery material out of the tube. What is it? It is mercury.

Wouldn't you call this a good magical experiment? Who would ever think that from a red powder you could get a silvery liquid and a gas that makes things burn more brightly? Now that you have seen this happen, you of course want an explanation. How can a red powder change into mercury and a gas? You probably know that this gas is oxygen.

One thing we can be sure of. The mercury and the oxygen must have come from the red powder. There was no other material for them to come from. This, of course, can mean only one thing: The red powder must be made of two materials, mercury and oxygen. When we heated the red powder, we must have caused it to separate into the materials of which it is made. From its name, *mercuric oxide*, you might have guessed that the red powder was made of mercury and oxygen.

A material, such as mercuric oxide, that contains two or more simpler materials, is called a *compound*. The simpler materials that make up the compound are called *elements*. Elements cannot be separated into simpler materials. They are made of only one kind of material. Iron, gold, silver, mercury, and oxygen are examples of elements. No matter what we do with them, we cannot separate them into simpler materials.

A strange thing about a compound is that we cannot see any of the elements in it. You can grind mercuric oxide into the finest kind of powder and look at it under the most powerful microscope, and still you will not see any silvery liquid. Perhaps another example will make this clearer. Water is a compound. It is made of two gases, hydrogen and oxygen. Hydrogen is the gas that was used to fill the dirigible *Hindenburg*. You will

FIG. 112. Here you see the giant airship *Hindenburg* plunging nose first to the ground. The accident was caused by the burning of the hydrogen used in it. This scene shows you vividly how dangerous hydrogen may be, yet water is more than half hydrogen.

remember that the hydrogen caught fire, and the dirigible was destroyed. Oxygen, as you know, is the gas in which things burn brightly. Here we have an example of a burnable gas and of a gas that makes things burn; we put them together, and they form a liquid that we use to put out fires. Strange, isn't it? But we know that it is true because scientists can take water apart and get hydrogen and oxygen. They can also put hydrogen and oxygen together and produce water.

So we cannot tell whether a material is an element or a compound by looking at it. Even if we know that a material is a compound, we cannot tell by looking at it what elements are in it. But there is one kind of man who makes a business of doing this. That man is the chemist. As you study more about science, you will learn of many other wonderful things that the chemist can do.

WHAT ARE SOME COMMON ELEMENTS AND COMPOUNDS? Through years of experimentation and discovery the chemist has found that there are only ninety-two different elements. Some elements are hard, shiny substances, such as iron, copper, nickel, aluminum, silver, gold, and zinc. The element mercury is a liquid. Other elements, such as hydrogen, oxygen, helium, nitrogen, and chlorine, are gases. All of the 300,000 different materials in the world are made from these ninety-two elements.

Think of that! If you could take apart everything in the world, from roller-skates and candy to elephants and trees, and put the materials in separate piles, you would have only ninety-two different piles. We might call these ninety-two elements the building blocks of our materials. Sometimes we make things from the elements themselves, as with gold and lead. Sometimes we put elements together and use them in compounds.

Even our bodies are made of elements. A scientist has figured out that the body of a man weighing 160 pounds contains enough iron to make a tenpenny nail, a small teaspoonful of sugar (a compound made of carbon, hydrogen, and oxygen), enough fat (a compound of carbon, hydrogen, and oxygen) to make several bars of soap, several cups of lime (calcium), enough phosphorus to make a large box of matches, and enough potassium to make the powder for a small shot-gun shell.

It would be very interesting to make a collection of the different elements. You will find, however, that many of them are hard to obtain. Table 4 on the next page gives a list of the most common elements and some of their characteristics and uses.

Following each element you will find in the next column the *symbol*, or sign, for the element. Instead of writing the whole word, the chemist uses one or two letters to stand for the name of the element. If you study chemistry, you will learn the symbol for each

TABLE 4. Some Common Elements

Element	Symbol	Appearance	Uses (either alone or in compounds)
Aluminum	Al	Light silver-colored metal	Kitchen pans, airplane parts
Calcium	Ca	Silver-white metal	Compounds: limestone, quicklime, mortar, bleaching powder
Carbon	C	Black solid or clear crystals	Pencils, coal, diamonds
Chlorine	Cl	Greenish-yellow poisonous gas	Bleaching compounds, table salt; used to kill germs
Chromium	Cr	Silver-white metal	In stainless steel and rustproof plating
Copper	Cu	Brownish-gold metal	Kitchen utensils, wire for electric current
Gold	Au	Yellowish metal	Jewelry, fillings for teeth
Helium	He	Light colorless gas	Inflating balloons
Hydrogen	H	Light colorless gas	Inflating balloons, blow-torches
Iodine	I	Purplish-black crystal	Killing germs
Iron	Fe	Silver-white metal	Construction purposes
Lead	Pb	Soft bluish-white metal	Paint, pipes, solder, shot
Mercury	Hg	Silver-colored liquid	Thermometers, barometers
Neon	Ne	Colorless gas	Advertising signs
Nickel	Ni	Hard silver-white metal	Coins, plating other metals
Nitrogen	N	Colorless gas	Fertilizers, explosives
Oxygen	O	Colorless gas	Burning, blow-torches
Phosphorus	P	Waxy yellow solid	Matches, rat poison
Platinum	Pt	Soft white metal	Jewelry, wire
Potassium	K	Waxy bluish-white metal	Many compounds
Silver	Ag	Soft white metal	Coins, jewelry, silvering mirrors
Sodium	Na	Waxy silver-white metal	Table salt, baking soda, etc.
Sulphur	S	Yellow solid	Matches, fireworks, gunpowder, dyes
Tin	Sn	Soft white metal	Tin-foil, plating, solder
Tungsten	W	Heavy silver-white metal	Electric lamp filaments
Zinc	Zn	Bluish-white metal	Electric batteries, covering on galvanized iron

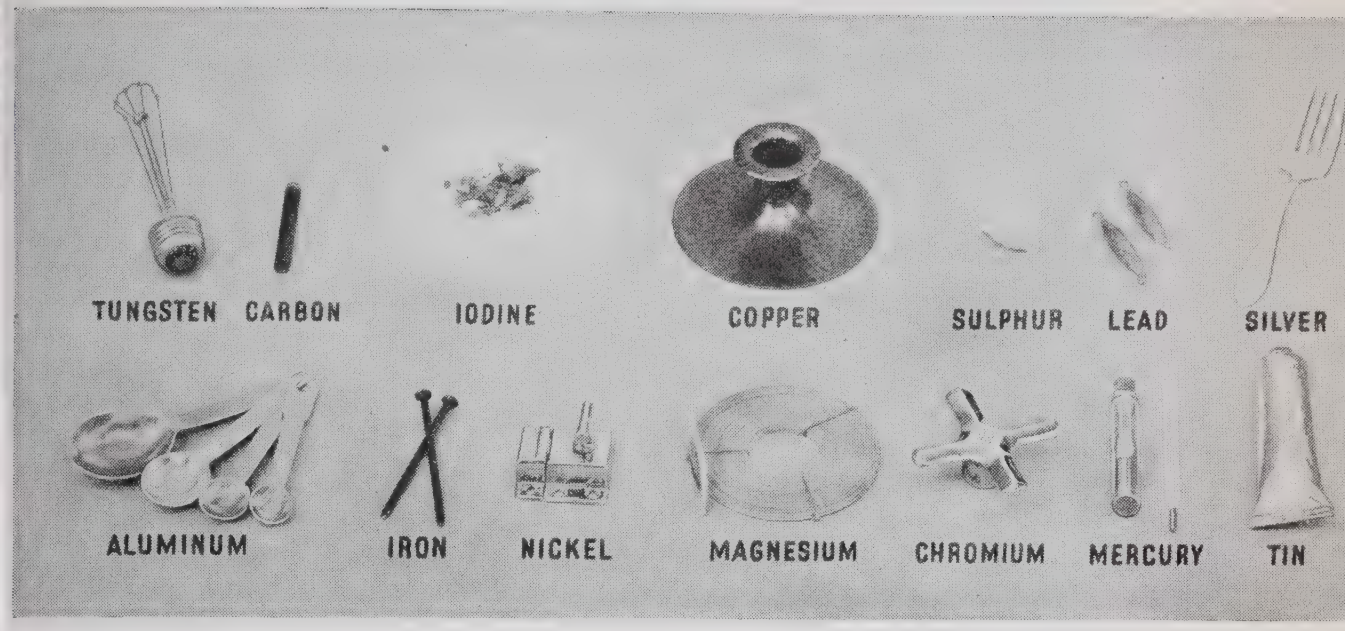


FIG. 113. How many of the common elements in this collection do you recognize? The wire, or filaments, in the electric light bulb are tungsten. The faucet handle is iron, plated with chromium. Most tooth-paste and shaving-cream tubes are made of tin.

element, but this is not necessary now unless you wish to memorize a few of them.

Table 5 gives a list of some of the common compounds. How many of them do you know? You will also find the *formula*, or abbreviation, for each of the compounds. In some of these formulas there are little numbers. You do not need to know exactly what these numbers mean, but the chemist uses them to tell how much of each element it takes to make the compound.

Notice that each formula contains two or more symbols. You would expect this, because compounds are made of two or more elements. From this table you can tell what elements are in each compound. For example, let us take table salt. The chemical name is *sodium chloride*, and the formula is NaCl. Na stands for sodium, and Cl stands for chlorine. In Experiment 11

FIG. 114. In Table 5 you will find the chemical formula for each of these common compounds and how each compound is used.

you discovered that mercuric oxide contains mercury and oxygen. The chemical formula for mercuric oxide is HgO. Hg stands for mercury, and O stands for oxygen. Refer to Table 4 and see if you can tell what elements are in each compound given in Table 5.

TABLE 5. SOME COMMON COMPOUNDS

Common Name	Chemical Name	Formula	Uses
Alcohol	Ethyl alcohol	C_2H_5OH	Dissolving things
Alum	Potassium aluminum sulphate	$KAl(SO_4)_2$	Baking-powder
Ammonia water	Ammonium hydroxide	NH_4OH	Cleaning
Baking soda	Sodium bicarbonate	$NaHCO_3$	Baking
Blue vitriol	Copper sulphate	$CuSO_4$	Killing fungi and copper plating
Carbona	Carbon tetrachloride	CCl_4	Cleaning fluid
Chile saltpeter	Sodium nitrate	$NaNO_3$	Fertilizer
Chloroform	Trichlormethane	$CHCl_3$	Anesthetic
Limestone	Calcium carbonate	$CaCO_3$	Building
Lye	Sodium hydroxide	$2NaOH$	Cleaning, manufacture of soap
Plaster of Paris	Calcium sulphate	$(CaSO_4)_2 \cdot H_2O$	Molds and casts
Quicklime	Calcium oxide	CaO	Mortar
Sand	Silicon dioxide	SiO_2	Building
Sugar (cane)		$C_{12}H_{22}O_{11}$	Food
Table salt	Sodium chloride	$NaCl$	Seasoning food
Washing-soda	Sodium carbonate	Na_2CO_3	Washing, manufacture of glass

Self-Testing Exercises

1. What is a compound?
2. How is an element different from a compound?
3. Can you tell what elements are in a compound by looking at it? Give an example to help explain your answer.
4. We say that elements are the building blocks of other materials. What do we mean by this?

Problems to Solve

1. List the elements in Table 4 that you have heard of. Place a star in front of those in your list that you have seen.
2. Refer to Table 5 and find all the compounds that contain sodium. How do these compounds help you to understand why so many materials can be made from ninety-two elements?
3. When someone tells you that gold is an element, what do you immediately know about gold?
4. Iron rust is a compound. What does this tell you about rust?

Problem 2:
HOW CAN WE RECOGNIZE A CHEMICAL CHANGE?

HOW DO WE TELL ONE SUBSTANCE FROM ANOTHER? You have learned that chemists have found over 300,000 different kinds of materials or substances. It hardly seems possible that there can be so many different kinds. It seems even more strange that the chemist can tell all these different substances apart. But he can. If you give him a sample of any substance, he will tell you what it is. It may take him several days to find out, because he may have to make many tests.

Even a person who is not a chemist can recognize some of the common materials. If someone hands you a piece of clean copper and a piece of clean aluminum, you can tell them apart instantly. You know the copper by its reddish color and the aluminum by its silvery color

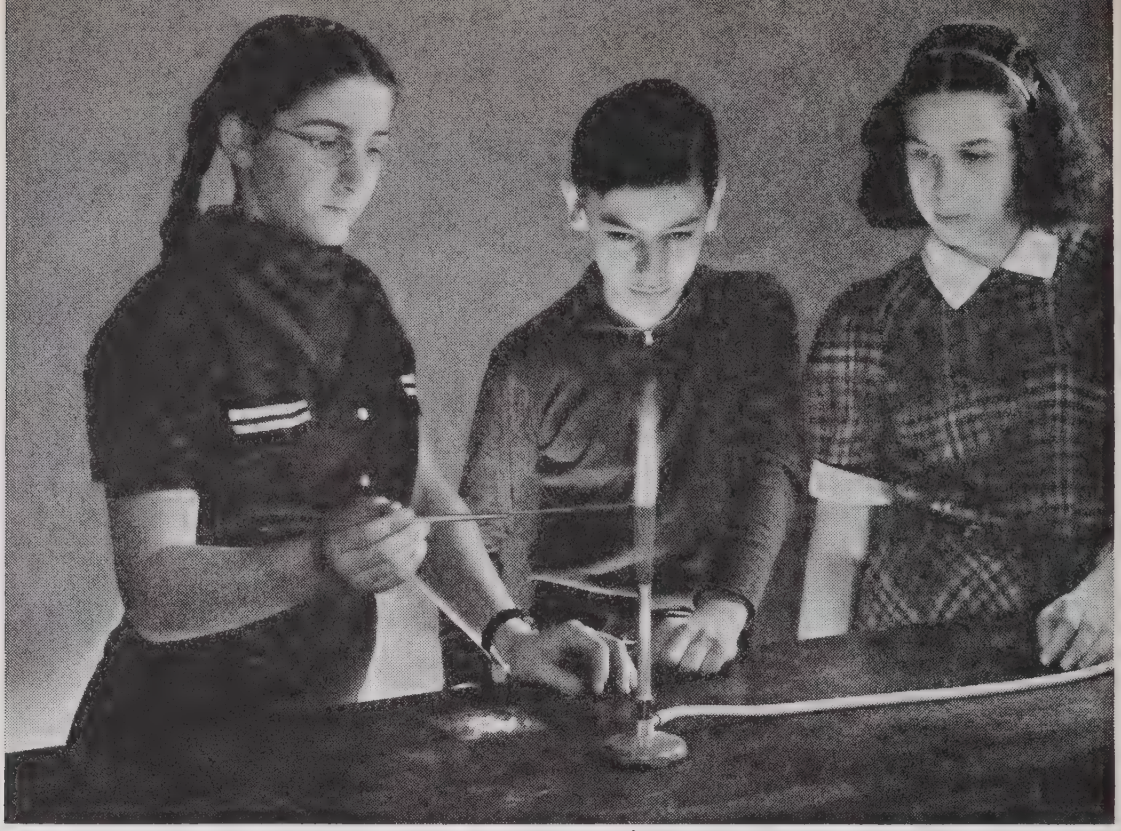


FIG. 115. Apparatus for Experiment 12a

and by its lightness. We recognize things in various ways: by looking at them to see their color and general appearance; by lifting them to feel their weight; or by smelling, touching, or tasting them. By doing these things we are able to describe the material. We say a substance has certain characteristics. For example, the characteristics of pure water are: it is a liquid; it is tasteless, odorless, and colorless; it boils at 212° F., and it freezes at 32° F.

Of course, it would be impossible to recognize the 300,000 different kinds of materials just by looking at them, touching them, tasting them, and smelling them. Let us see how chemists test materials.

EXPERIMENT 12. *How Do Chemists Make Tests to Tell What a Substance Is?* (*a*) Get about ten inches of small iron wire. Bend one end of the wire into a loop or circle about one-eighth inch across. Clean this end of the iron wire by dipping it into dilute hydrochloric acid and holding it in the blue flame of a Bunsen burner until it does not noticeably color the flame.

Moisten a little table salt on a glass plate with strong hydrochloric acid. Dip the wire loop into the moistened salt and heat it in the edge of the blue flame. What color is the flame?

Make another wire loop and repeat the experiment. This time use very pure potassium nitrate or any potassium salt, very pure calcium chloride or any calcium salt, and copper sulphate or any copper salt. What color is each flame?

b) Place a little starch in water. Add a few drops of dilute iodine solution. What change in color takes place? Scrape some of the white part of a potato to get a pulpy mass. Put a drop or two of iodine on it. What color does it become?

The two tests that you have made give you an idea of how the chemist works. The first test is called the *flame test.* You saw that different materials gave the flame different colors. If a chemist has an unknown material, he usually first uses the flame test. This test is only a beginning one; it gives him a hint as to what the material may be. He follows this up with other tests.

The second test is the *starch test.* When iodine is added to starch, the starch turns blue or blue black. Chemists have found that this will not happen with any other substance. Therefore, the chemist knows that if an unknown substance turns blue or blue black when iodine is added, the substance must have starch in it. There are many different kinds of tests that the chemist uses to find what materials are made of.

Self-Testing Exercises

1. Select some material such as glass, rubber, silver, or cork and name as many of its characteristics as you can.

2. How does a chemist discover the characteristics of a material?

3. If a chemical test for a substance works only part of the time, is the test of any value to the chemist? Why?

FIG. 116. Apparatus for Experiment 13

WHAT HAPPENS TO THE CHARACTERISTICS OF A SUBSTANCE DURING A CHEMICAL CHANGE? If you have ever made a cake, dyed a dress, taken a photograph, lighted a fire, or eaten a piece of bread, you caused a chemical change. You also have seen the results of many chemical changes. When food spoils, fountain-pen ink changes color, newly laid concrete roads become hard, the leaves on the trees change color, or a piece of wood decays, chemical changes are going on.

It does not seem possible that the chemical changes in all of those different materials would be alike in some ways. But they are, as you will soon see. To discover what happens in a chemical change, let us first do a few experiments.

EXPERIMENT 13. *What Happens When Wood Is Heated?* Get a piece of wood about two inches long and small enough to go inside a test-tube. Fit a cork to the test-tube. Bore a hole in the cork and in the hole put a piece of glass tubing

about three inches long. Put the cork in the test-tube and clamp the test-tube on a ring stand. Heat the tube strongly, moving the flame around so that all the wood is heated but the glass does not melt.

What do you see in the test-tube? Touch a flame quickly to the end of the glass tube. What happens? Heat the wood until no more gas is made. What is left in the test-tube? Take the material out and examine it.

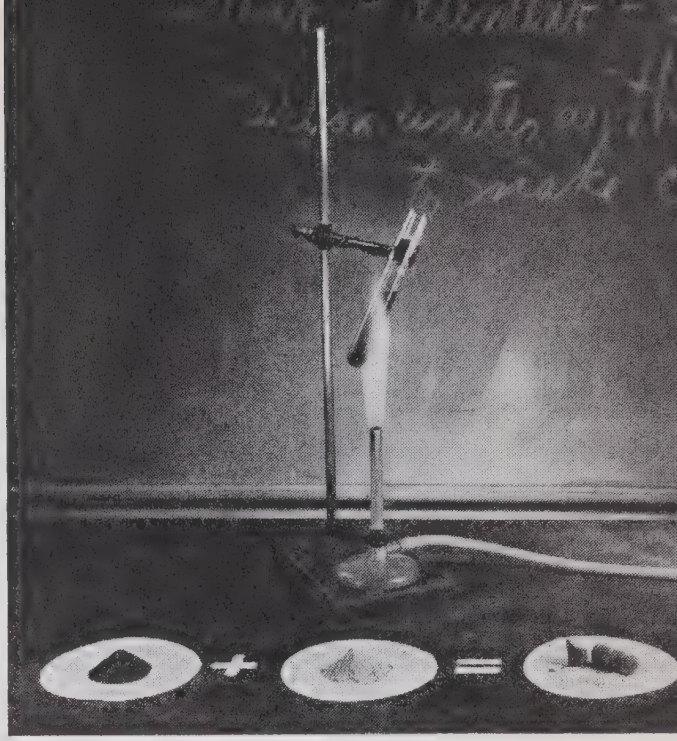


FIG. 117. Experiment 14

EXPERIMENT 14. *What Happens When Sulphur and Iron Are Heated Together?* (*a*) Mix together in a dish one-third of a test-tube of iron powder and one-third of a test-tube of powdered sulphur.

Pour some of the mixture into a test-tube of water and shake it thoroughly. Allow it to stand for awhile. What is in the bottom of your tube? What settles last?

b) Pour the remainder of the mixture into a test-tube and heat until the sulphur melts and a red glow spreads all through the mass. Break the test-tube to remove the material; then break the material into small pieces. Does it look like iron or sulphur? Pour some of the material into a test-tube of water and shake it thoroughly. Allow it to stand for awhile. How do you explain what happened in this experiment?

In each of these experiments a chemical change took place. To find what happened, let us first study the characteristics of the materials before and after the chemical change.

The wood in Experiment 13 had certain characteristics. It was white or yellowish white; it could be cut with a

FIG. 118. When sulphuric acid is poured over sugar, it removes water (hydrogen and oxygen) from the sugar, leaving black carbon. The heat and water that are produced form steam, which puffs the carbon into a spongy mass.

knife; it had a certain weight; and it would burn with a flame. When it was heated, whitish-colored fumes were given off. Left in the tube was a black solid called *charcoal.* This black material was mostly the element carbon. As a result of heating, the wood changed into two kinds of materials. It changed into gases and carbon. Neither of these materials has the same characteristics as the wood. The wood is no longer wood; it has been changed into something else. This is what always happens when a chemical change takes place. The material becomes a different material. Or it may become two or three materials, all different from the first material.

Now let us see what happened in the experiment with iron and sulphur. When the powdered iron and sulphur were just mixed together, they could be easily separated by putting the mixture in water. The heavy iron particles quickly settled to the bottom. Then the lighter sulphur particles settled on top of the iron. No change had taken place in the iron and sulphur. This we

know because their characteristics were just the same as they were before the materials were mixed together.

After they were heated together, they could no longer be separated by mixing with water. A chemical change had taken place. The iron and sulphur had *combined*, or gone together, to form a new material. This new material that was made is called iron sulphide. It is a compound of iron and sulphur. This new material is not like iron. Neither is it like sulphur. As a result of the chemical change, a new material with characteristics of its own has been formed.

Now let us recall two other chemical changes that we have studied. You remember that mercuric oxide changed into mercury and oxygen when it was heated. And you remember that oxygen and hydrogen can be put together by the chemist to make water. All of these chemical changes are alike in one way: the material or materials that are formed are different from the materials you started with. You know that this is true because these new materials have different characteristics from the materials you started with.

Self-Testing Exercises

1. How can you tell when a chemical change has taken place?

2. How do you know that a chemical change took place when wood was heated? When iron and sulphur were heated? When mercuric oxide was heated?

3. Explain how you know that the chemical changes in the first pargraaph on page 162 are really chemical changes.

4. Make as long a list as you can of other chemical changes that are going on around you. In each case, explain how you know that it is a chemical change.

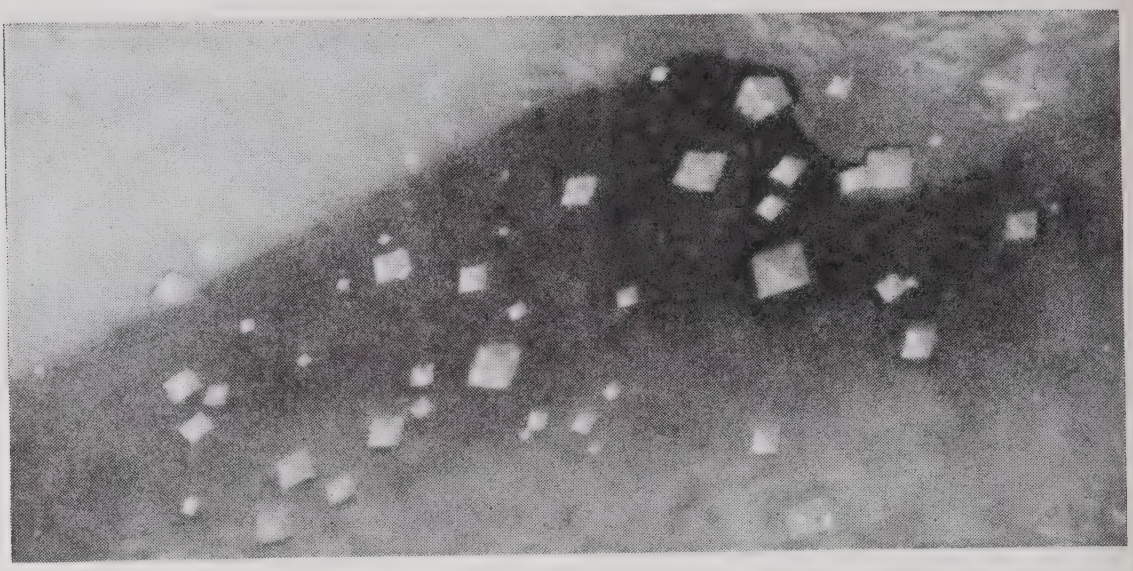


FIG. 119. A solution of salt water is being evaporated in open pans over steam pipes. Salt crystals are forming on the surface. This fact tells you whether the solution is a mixture or a compound. Which is it? Why?

WHAT ARE MIXTURES? Most of the materials around us are neither pure elements nor pure compounds. They are *mixtures* of elements and compounds. You can see that this is true if you add a handful of soil to a tall jar containing water. Shake the mixture well and allow it to stand until the soil settles. When you examine it, you will find different layers of materials. You will see that the soil contains large and small particles of stone or sand, clay, and decayed plant materials. Soil is not a compound. No chemical change took place when the materials were mixed together. No new material was formed. Soil is simply a mixture of elements and compounds.

Air is also a mixture; it is a mixture of gases. Air contains large amounts of the elements nitrogen and oxygen. These are mixed with small amounts of water and carbon dioxide, which are compounds. Air also contains

very small amounts of certain rare gases. Milk is a mixture of water, fats, sugar, and other materials. Water, fats, and sugar are all compounds. Wood, paper, cloth, glass, and even your own body are mixtures of elements and compounds.

Now let us see what you have learned about the way materials are made. All the materials in the world are made of elements. Some materials contain only one element. In some materials the elements are combined into a compound. If a material contains only one element or only one compound, the chemist calls the material *pure*. Iron and iron rust are pure materials. One of them is a pure element, and one is a pure compound. Sugar is also a pure compound. Air, soil, and milk are not pure substances. They are neither pure elements nor pure compounds. They are mixtures of elements and compounds.

Self-Testing Exercises

1. Do you think that there are many mixtures in the world, or only a few?
2. What is meant by a pure substance?
3. When you stir sugar and sand together, do you make a mixture or a compound? Explain why you think your answer is right.
4. Do you think that solutions are mixtures or compounds? Why?
5. Why is soil not a pure substance?

Problems to Solve

1. On page 168 you will find listed a number of changes that take place in materials. Which ones do you believe are chemical changes? Which ones are not chemical changes? To answer these questions you must get clearly in mind what

happens when a chemical change takes place. Then you must study each of the changes to see if it is a chemical change.

a) Butter melts when it is heated.
b) Matches take fire when rubbed on a rough surface.
c) Water freezes if cooled below 32° F.
d) Rock is often crushed into small pieces.
e) Green leaves become yellow when they are kept in the dark.
f) Meat decays if it is not kept properly.
g) Gasoline evaporates if left in an open dish.
h) A green coating forms on copper roofs.
i) Aluminum may be pressed into thin sheets.
j) A fire-cracker explodes when it is lighted.
k) Kodak films are spoiled if exposed to light.
l) Sugar dissolves in water.
m) The whites of eggs become fluffy when beaten.
n) When colored clothes are washed in water containing ammonia, they often fade.
o) A silver spoon that is used to stir scrambled eggs will become black if it is not cleaned.
p) Straw hats that have become yellow are made whiter with lemon juice.

2. Materials need oxygen in order to burn. Materials will burn in air that contains oxygen. Water is made of hydrogen and oxygen, but materials will not burn in water. Explain.

3. Iron rust contains oxygen and iron. Why can you not use a magnet to separate the iron from the oxygen?

4. When we put sugar into tea, do we cause a chemical change? How do you know?

5. Richard was playing with his new chemistry set. He poured some clear liquid into a test-tube that contained some white powder. The solution in the tube became very hot and gave off a bad odor. A dark mass of solid material settled to the bottom of the test-tube. Do you think that he had caused a chemical change? Tell why you think so.

FIG. 120. Heat causes many chemical changes to take place. In this forest heat from forest fire has changed many of the materials in the trees and the other plants.

Problem 3:

HOW CAN WE CONTROL CHEMICAL CHANGES?

PERHAPS you have seen labels like these on boxes or bottles: "Keep in a cool, dark place." "Do not use near an open flame." "Keep in a dry place." Have you ever seen this caution on a box of kodak film: "Do not open in the light"? Why do you suppose these statements are printed on the labels? They are put there so that you will know how to keep the materials from spoiling. And if you do not follow directions, they will spoil because harmful chemical changes will take place. Let us see what some of the things are that make chemical changes take place.

HOW CAN WE MAKE HELPFUL CHEMICAL CHANGES TAKE PLACE? You have already seen that you can make chemical changes take place by heating materials. When iron and sulphur were heated together in Experiment 14, iron sulphide was produced. We use heat when we strike a match. When the match is rubbed on a rough surface, there is *friction* between the two rubbing sur-

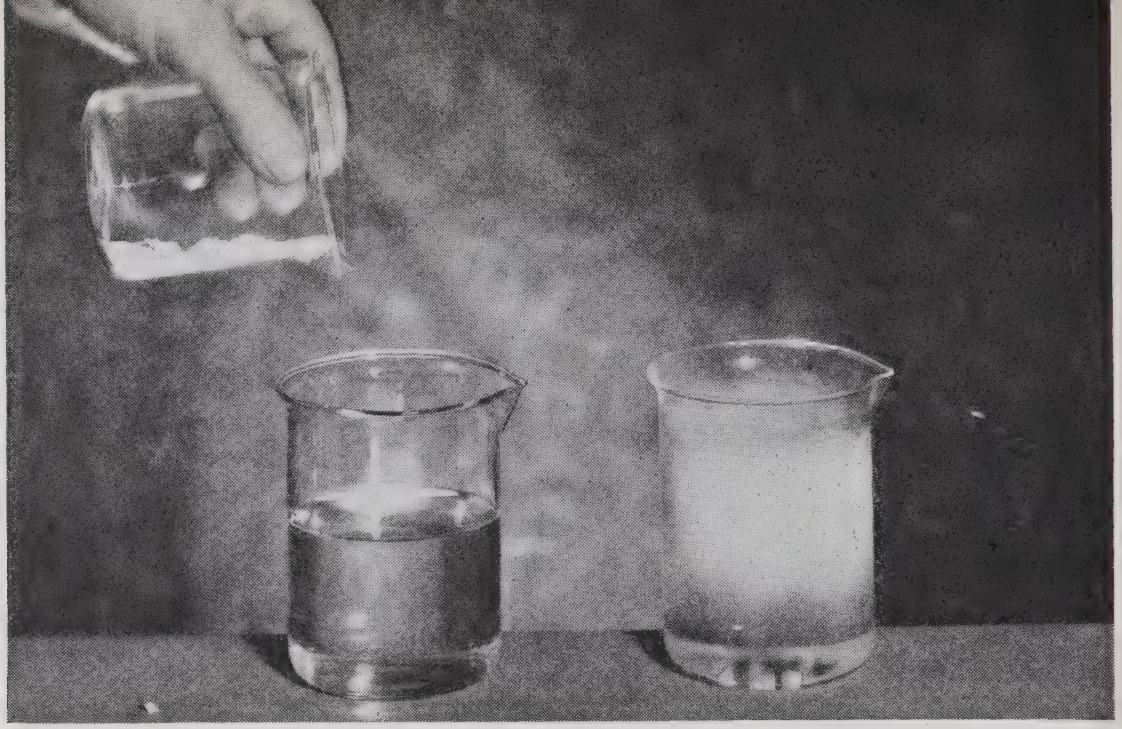


FIG. 121. In the upper beaker is a mixture of two white powders. Mixing them does not change them until they are poured into water. Then, as shown in the beaker at the right, something very definite happens. (See Experiment 15.)

faces. This friction heats the match, and the heat causes a chemical change. The materials on the match combine with the oxygen in the air and begin to burn. Of course, the same thing happens if you touch a match head to a hot stove. Chemical changes are more rapid when the materials are heated.

Many chemical changes will not take place at all unless the materials are heated to a high temperature. For example, iron ore as it is mined from the earth is a compound of iron and oxygen (Fe_3O_4). To get iron, we must separate the oxygen from the iron. First, coke (carbon) is mixed with the iron ore. If the iron ore and coke are merely mixed together, nothing happens. But if the mixture is heated to a high temperature in a big furnace, the coke takes the oxygen away from the iron.

Glass is made of soda, sand, and limestone. When these materials are heated to a high temperature, they melt, mix together, and go through chemical changes

that turn them into the transparent glass that we use for windows, tumblers, and other articles.

The following experiment will show you another way of bringing about chemical changes.

EXPERIMENT 15. *Can We Bring About Chemical Changes by Dissolving Substances?* Mix a half teaspoonful of citric-acid crystals and a half teaspoonful of baking-soda. Be sure to keep the mixture dry. Does any change in these chemicals take place? Pour the mixture into a half test-tube of water. Does a chemical change take place? How can you tell? Did dissolving the chemicals help the change to take place?

As long as the citric acid and the baking soda are kept dry, no chemical action takes place. When they are mixed with water, a gas (carbon dioxide) is made, which shows that a chemical change has taken place. Water helps many chemical changes to take place.

EXPERIMENT 16. *Are Chemical Changes Brought About by Light?* Dissolve some silver nitrate in water. Fill two test-tubes about one-fourth full of the solution. Keep one tube in a dark place. Put the second tube in the bright sunlight for several minutes. Watch the solution in the second tube carefully during this time. Is there any change in the appearance of the chemical? Take the tube out of the dark place and compare it with the tube that has been in the sunlight. Is there any difference in their appearance? If so, what do you think caused the change?

In this experiment the light causes the silver nitrate to turn dark. Something like this happens when you take a picture with a camera. The film has in it a chemical that is easily changed by light. When you open the shutter of the camera for an instant, light strikes the film and makes a chemical change in it.

You can see another example of a chemical change caused by light if you make a blue-print. Place a coin on some blue-print paper and put it in sunlight for a short time. Then wash the paper in water. The part that was in the light will be blue, and the part that was under the coin will stay white.

You can see that there are several ways of bringing about chemical changes and causing them to take place more easily. The way we make each change take place depends on the substances we are using.

Self-Testing Exercises

1. Describe three ways of making chemical changes take place.

2. Study Experiments 11, 12, 13, 14, 15, and 16 and tell what method of bringing about chemical change was used in each experiment.

Problems to Solve

1. If you examine books that have been kept in cases for several years, you will find that the backs of the books are not as bright colored as the sides. Explain.

2. When a picture is taken off a wall, the paper or paint back of the picture is usually darker or lighter than the rest of the wall. Explain.

3. Which methods have you used to bring about chemical changes?

4. What chemical change takes place when an automobile engine is running? What makes the change take place?

How can we stop harmful chemical changes?

Many of the materials that we need are constantly spoiling because we cannot or do not stop chemical changes in them. Experiment 17, on the next page, will show you one method of preventing a chemical change.

EXPERIMENT 17. *How May One Kind of Chemical Change Be Prevented?* Dip half of a piece of bright new iron into paint. (A large nail will do.) When the paint has dried thoroughly, put the piece of iron into a glass jar. Put a small sponge filled with water into the jar with the iron. Seal the cover tightly on the jar. Allow the jar to stand for several days. What part of the iron is covered with rust? From what was the rust formed? Scrape the paint from the part of the iron that is coated. Did the part of the iron under the paint rust? Explain.

FIG. 122. This piece of pipe is rusted so badly that part of it is iron oxide instead of iron.

Now you see why bridges, fences, and other objects made of iron are painted. If they are not painted, the oxygen in the air will combine with the iron and form iron oxide, or rust. The chemist knows this; so he looks for something to keep the oxygen in the air from touching the iron. The material he uses must not combine with the iron, either. Paint, he has found, does not change the iron, and it does keep away the oxygen. Oil will do the same thing. If tools are not often used, it is a good plan to wipe them with an oily rag when they are put away. If you do not want chemical changes to take place, you can sometimes stop the changes by keeping materials away from each other.

You can also understand why some bottles and boxes are labeled "Keep in a dark place." Light would cause a

harmful chemical change to take place. Since many of us are careless, our chemicals are often put in dark-colored bottles to keep out the light. Have you ever noticed that "peroxide" (hydrogen peroxide, H_2O_2) is sold in brown bottles? When hydrogen peroxide is left in a strong light, it separates into oxygen and water.

If a bottle is labeled "Keep in a cool place," you know that chemical changes will take place if the material in the bottle gets too warm. And you can now see why baking-powder must be kept dry. Even the moisture in the air will cause chemical change and spoil the baking-powder.

Man has often been called a "thinking animal." This is because he can use his mind to solve many of his problems. Thinking of ways to control chemical changes is only one of his many problems, but it has helped to change his life from primitive ways to our ways of living today. Can you suggest some other chemical changes that man needs to learn to control?

Self-Testing Exercises

1. Name all the ways that are given in this problem for preventing chemical changes.
2. Which of these methods have you used?

Problems to Solve

1. When colored clothes are washed, it is much better to dry them in the shade. Why?
2. You can buy prepared pancake flour in a store. Why do you suppose it must be kept dry?
3. Why does food turn black if it is left on a hot stove too long?
4. Why should milk usually be kept cold?

Problem 4 (Optional):

WHAT ARE THE TWO KINDS OF SIMPLE CHEMICAL CHANGES?

WHAT IS CHEMICAL COMBINATION? Do you remember the change that took place when iron was heated with sulphur? The iron and sulphur changed into *one* new substance. This new substance was a compound containing iron and sulphur, and the change that made them into a new substance is called chemical *combination.* We say that the iron *combines* with the sulphur. The rusting of iron is another example of chemical combination. The iron combines with the oxygen from the air, and iron oxide, or rust, is formed.

Chemical changes are going on all the time in nature, and scientists are constantly putting together substances to make things that we need. They can make chemical combinations take place because they have learned the laws of chemical change.

You have learned about the symbols and formulas that chemists use for elements and compounds. Chemists also have a way of telling what chemical combination has taken place. They show this by an *equation.* To see what a chemical equation is like, let us take the combination of iron and sulphur to make iron sulphide. We could show this combination by writing it out in two sentences, thus:

One element + another element makes a compound.

Iron + sulphur makes iron sulphide.

But a chemist would show this change by an equation:

$$Fe + S \rightarrow FeS.$$

As you study science, you will find many examples of chemical combination. And you will also learn of many

combinations that scientists make to give us substances and materials that we need.

Now you must not get the idea that any two elements can be combined to form a new compound. For example, you cannot make copper and gold combine to form a compound. It has taken chemists hundreds of years to discover what elements will combine with each other. You would have to study chemistry to know what elements may be combined and how to make them combine.

WHAT IS DECOMPOSITION? In the second kind of simple chemical change we start with a compound. You remember that you heated mercuric oxide and changed it into two substances, mercury and oxygen. The chemical change that took place as the mercury and oxygen separated is called *decomposition*. We may say that the mercuric oxide was *decomposed* into mercury and oxygen.

This kind of chemical change is just the opposite of combination. In decomposition we say that a compound changes into one element plus another element. Mercuric oxide separates into mercury plus oxygen. A chemist would use this equation to show the decomposition of mercuric oxide:

$$HgO \rightarrow Hg + O.$$

In Experiment 13 the wood decomposed when it was heated. A great deal of one element, carbon, was left in the test-tube. However, the gases that went away into the air or burned at the mouth of the test-tube were compounds. From this we see that a material may decompose into elements, or into compounds, or into both elements and compounds.

Not all compounds can be decomposed by heating

them with an ordinary burner. If you will stop to think, you will know that this is true. Water is a compound made of hydrogen and oxygen (H_2O). When you heat water, it merely changes into steam; it does not decompose. If you cool the steam, it changes back into water again. But water can be decomposed by passing a current of electricity through it, and in several other ways. Chemists have many different methods of decomposing compounds. If they did not know how to decompose compounds, we would not have many of the substances and materials that we use every day.

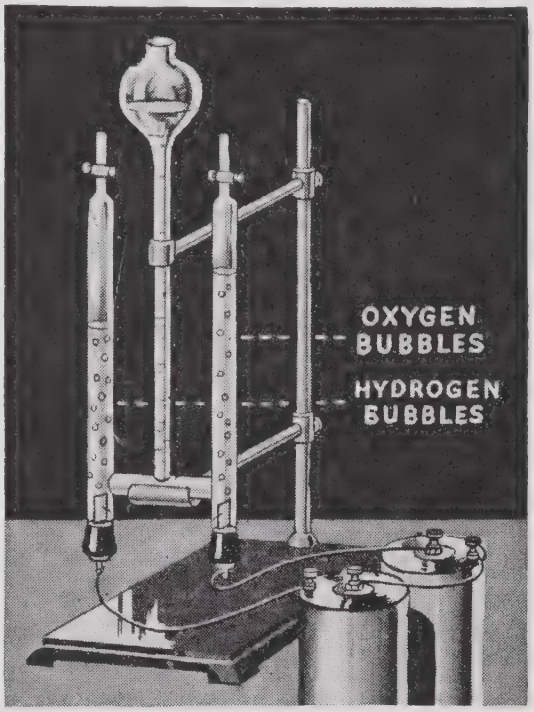


FIG. 123. With this kind of apparatus, electricity is sent through water, decomposing it into the gases oxygen and hydrogen.

WHAT ARE MOLECULES MADE OF? We already know that a substance, such as water, is made of molecules. A molecule is the smallest particle of water that can exist. The formula for water (H_2O) tells us that water is made of two elements, hydrogen and oxygen. Since each molecule of water is made of two elements, we know that there must be particles even smaller than the molecule. These particles are called *atoms*. Each molecule of water contains two atoms of hydrogen and one atom of oxygen.

Experiments have shown that some elements have one atom in a molecule, while others have two atoms. Gases,

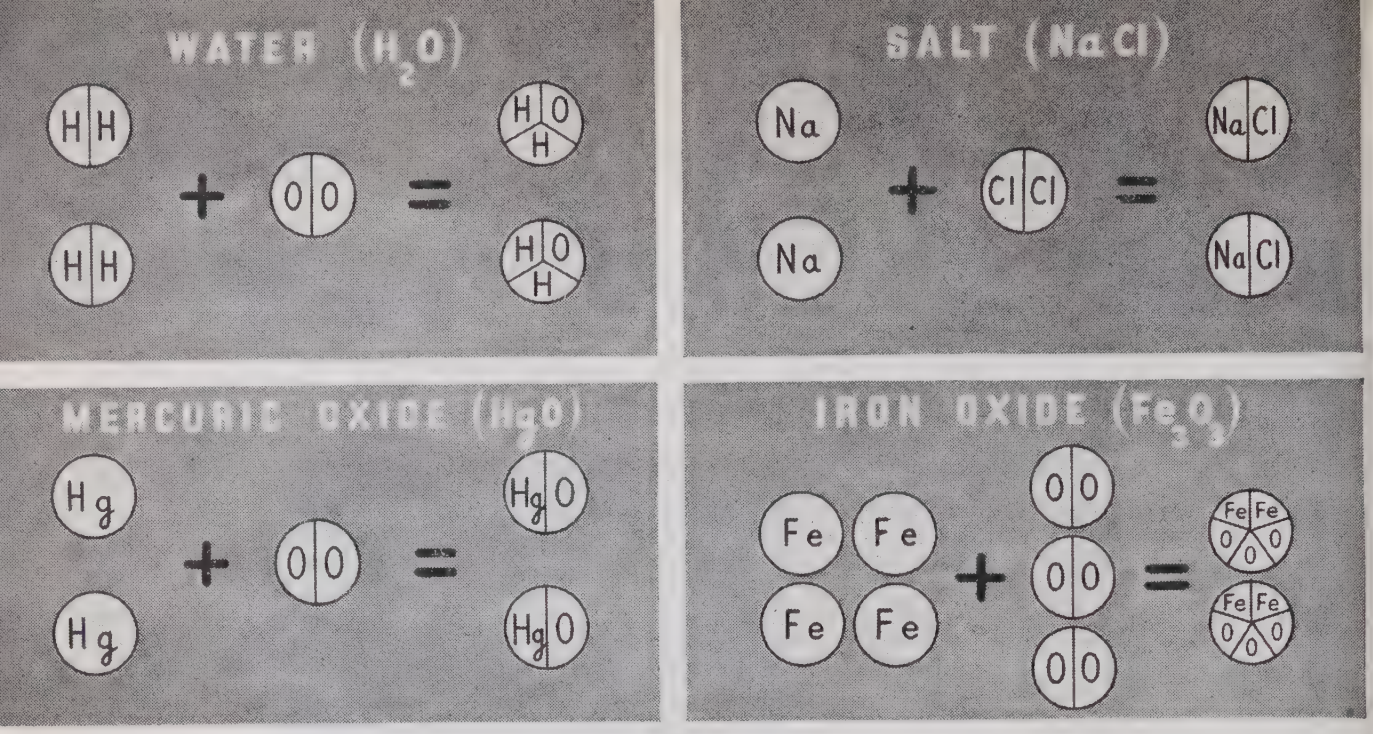


FIG. 124. Each circle represents a molecule of an element or a compound with the atoms in each. Of course, atoms in molecules do not look like this, but the diagrams may help you to see that molecules may contain different atoms. Thus, when 2 molecules (4 atoms) of hydrogen unite with 1 molecule (2 atoms) of oxygen, they form 2 molecules of water, each molecule having 2 hydrogen and 1 oxygen atoms. Explain the other diagrams.

such as hydrogen, oxygen, and nitrogen, have two atoms in a molecule. A molecule of any compound, of course, will always have two or more atoms in a molecule, because a compound always contains two or more elements.

When a chemical change takes place, there is always a change in the molecules. Two molecules of different substances may combine and form one molecule of a compound. This is what happens when iron combines with sulphur. One molecule of iron unites with one molecule of sulphur to make a molecule of iron sulphide. On the other hand, a molecule may be decomposed into its atoms. This happens when water is decomposed into hydrogen and oxygen. One molecule of water decomposes into two atoms of hydrogen and one atom of oxygen.

An interesting kind of chemical change may be seen if a clean iron nail is dipped for a minute into a solution of copper sulphate ($CuSO_4$). When the nail is removed, it

will have a coating of copper. This shows that some of the copper atoms must have been taken away from the copper sulphate. Experiment also shows that some of the iron from the nail took the place of some of the copper in the solution of copper sulphate. Thus, copper atoms were added to the iron, and iron atoms were added to the copper sulphate. Copper atoms were also taken away from the copper sulphate. The chemist writes the equation as follows: $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$.

There are many kinds of chemical changes. All of them are alike in one way: there is always some change in the *composition* of the substance, that is, in the kinds of atoms in the molecule of the substance.

Self-Testing Exercises

1. What does a chemist mean when he says two elements combine? What is produced when two elements combine?

2. (*a*) What does a chemist mean when he says that a material decomposes? (*b*) What kind of substance can be decomposed?

3. What kind of chemical change took place in Experiment 15?

4. A chemical change took place in Experiment 11. What characteristics of mercuric oxide were changed?

5. What happens to molecules during a chemical change?

Problems to Solve

1. Plants use chemicals from the air, soil, and water to make sugar. What kind of chemical change is this?

2. Table salt is a common food. It is composed of sodium, which will cause a sore if placed on the tongue, and a poisonous gas, chlorine. Explain why we can safely use the compound made from these substances.

3. If a candle flame is held close to a piece of glass, carbon will form on the glass. What kind of chemical change has taken place? Tell how you know.

4. When a tree decays, part of it changes to a gas that mixes with air, and part of it remains in the ground as minerals. What kind of change is this?

LOOKING BACK AT UNIT FIVE—SUMMARY EXERCISES

1. In this unit you have learned some more science principles that you can use to explain problems. Make a list of them, writing them as sentences, as you did for Unit Four.

2. Explain or define each of the following important science words used in this unit:

chemical change	*chemical formula*	*chemical symbol*
compound	*element*	*mixture*

ADDITIONAL EXERCISES

1. Carbon disulphide is a chemical with a bad odor that is often used in grain bins to kill insects. Why do the directions say, "Do not bring near an open flame"?

2. You may have seen baking-soda foam when it is mixed with a liquid. If you have not, put a teaspoonful into some water and see what happens. Is this a chemical change? Explain.

3. Charcoal is made by heating wood in air-tight ovens. What would happen to the wood if air were allowed to enter as it was being heated?

4. Iron rust contains iron and oxygen. Why can you not separate the iron from the oxygen with a magnet?

5. Copper statues become coated with a greenish-black scale when they are out-of-doors. What causes this scale to form?

6. Why do doctors often keep medicines in ice-boxes?

7. Heat some sugar in a test-tube. What makes you think a chemical change is taking place? Does the experiment show you anything that might tell you whether sugar is an element or a compound?

8. Mix a teaspoonful of quicklime with water. Does a chemical change take place? Explain your answer.

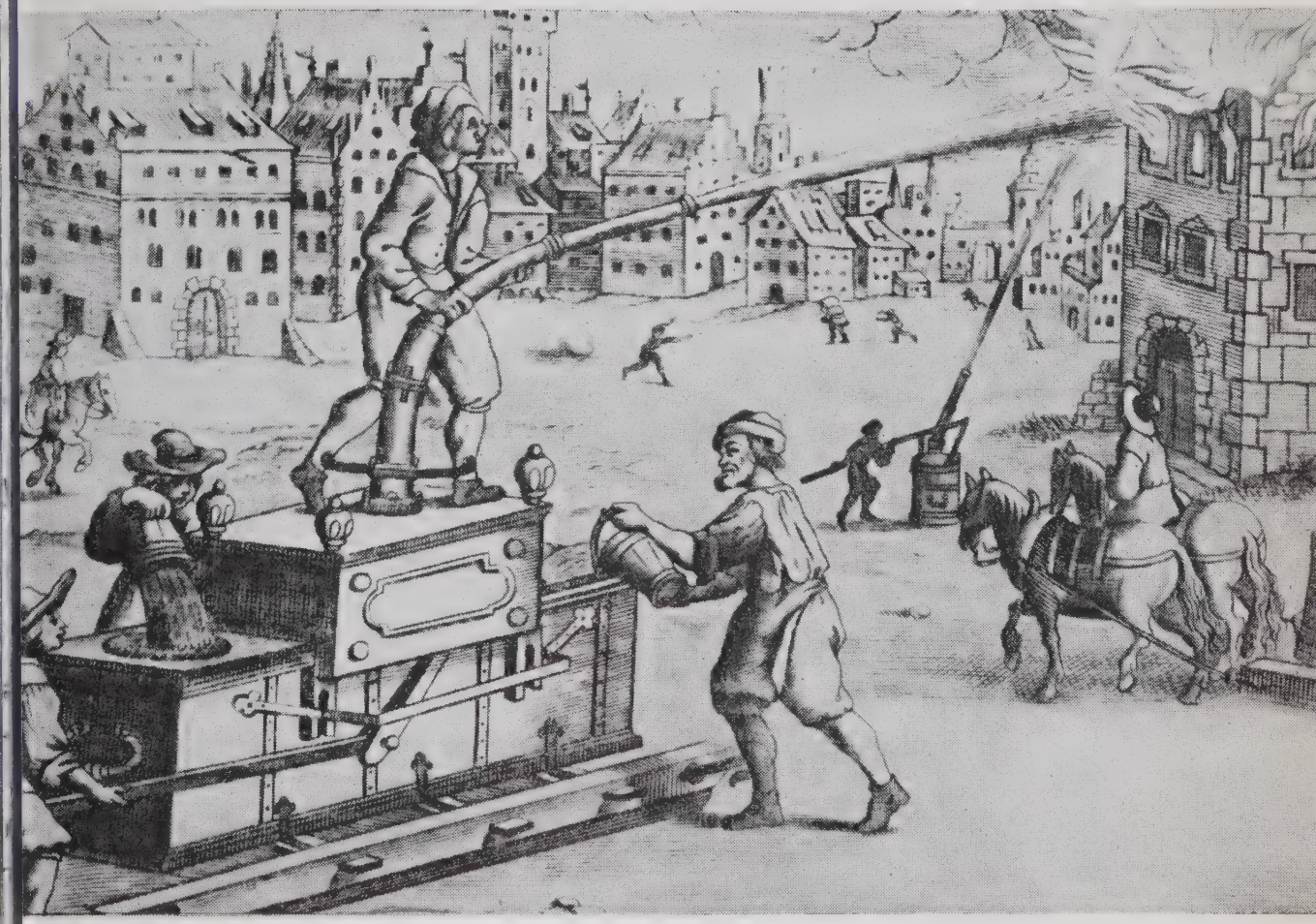


Fig. 125. In early times a fire was an even more terrible thing than it is today. There were no efficient fire departments to reach the fire quickly. Messengers ran through the streets, shouting, "Fire," or an alarm bell was rung. The volunteer fire-fighters came out helter-skelter and lost time in trying to locate the fire. Fire pumps have been known since Roman days. The hand fire pump above was used in Venice in 1608. Here you see men filling the water tanks and others working the pump that forces the water out.

UNIT SIX

UNIT 6

HOW DO WE USE AND CONTROL FIRE?

INTRODUCTORY EXERCISES

1. What becomes of the wax in a candle as it burns?

2. Is the burning of a candle a chemical change? Give reasons for your answer.

3. Divide your paper into two columns. In the left column make a list of all the kinds of fires you can think of. In the other column write what each fire did that was helpful or harmful. Put a star before the things that are helpful. Each fire may do more than one thing. The sample table below shows you how to do this exercise.

List of Fires	What Each Fire Did
1. Burning of leaves in street	*Got rid of the leaves Made a lot of unpleasant smoke
2. Coal fire in furnace	*Kept the house warm

4. To make a fire you must always have or do three things. What are these three things?

5. There are two ways of regulating fires so that they will burn at the correct rate. What are these two methods? Which method or methods are used in regulating a camp-fire? The fire in a coal furnace? In a gas-burner?

6. Write down several ways of putting out a fire without using a chemical extinguisher. Tell why each method you name puts out a fire.

7. What do you think are the most important causes of accidental fires? How could these fires be prevented?

FIG. 126. Almost everyone likes to watch a fire, whether it be in a friendly fireplace, a camp-fire in the woods, or a great building "going up in smoke." Some mysterious charm in the wavering flames, the glowing embers, and the rising smoke holds our attention.

LOOKING AHEAD TO UNIT SIX

MANY savage tribes, and some well-civilized races, have worshiped fire. And it is no wonder that man has often worshiped fire. Fire did more for him than almost anything else. With its light he could see at night and could scare away the wild beasts that threatened him. With its heat he could keep warm, cook his food, make weapons and tools, and change clay into brick and pottery. Fire burned his rubbish and helped clear the forests from the land he needed for his villages and his fields.

In early times making a fire was a hard task. It was hard because there were no matches in those days. For this reason an interesting custom became common in Egyptian, Persian, Roman, and Greek villages. Each village kept a public fire that was never allowed to go out. Here people came to get fire to light their fireplace and ovens. This public fire was so important

FIG. 127. These girls and the boy have learned a valuable lesson. They have learned that it is just as important to know how to put out a fire as it is to make one. They are throwing water on their camp-fire to be sure that no sparks are left to set dry grass on fire.

that sometimes village meetings were held around it.

Ignorant people may have worshiped fire also because they were afraid of it. They thought it was a devouring demon. It roared through woods and fields, destroying valuable hunting grounds as well as the homes and lives of the hunters. Some people probably worshiped fire because of its mystery. For thousands of years no one knew what really happened when things burned. Burning materials seemed to change into almost nothing. They gave off brightness and warmth like the sun. Only after centuries of thought and observation did chemists discover what fire is.

But even civilized people may well regard fire with respect. The ability to use fire is one of the things that

makes man different from the animals. Most of the things we have today would be impossible if we did not understand fire and know how to use it.

But what is there to learn about fire? Here is the story of a fire made by some explorers. Some of the words and statements are italicized. Each italicized part tells of something you should be able to explain when you really understand what fire is and how it is controlled.

An exploring party had been traveling all day through a forest. At dusk the leader chose a place to camp. The man who was to build the fire *cleared away the twigs and leaves from a wide space.* Other members of the party *brought in the fallen branches of trees.* Then the man *chose a dry stick* and with his knife *made a little pile of shavings and splinters* in the center of the cleared space. From a match box he took a match and *rubbed one end of it on the box.* There was a burst of light as *the match took fire.* With the burning match he set the shavings and splinters on fire. Carefully and slowly he piled *small* sticks and then larger ones *loosely* over and around the shavings.

Soon *the fire was giving enough light* so that the men could see to make camp. A column of bluish smoke *passed upward* into the darkness. *The fire gave out heat* that kept the explorers warm and cooked their food. Next morning *the great pile of wood was gone;* nothing was left *but a layer of gray ashes* and some *pieces of black charcoal.* A few "live coals" in the ashes helped to start another fire. When the explorers were ready to move on, they *threw water on the fire until they were sure that not even a spark remained.*

Problem 1:

WHAT HAPPENS WHEN THINGS BURN?

WHAT IS "BURNING"? You might think that the way to find out what happens when things burn is to watch them burn. To be sure, you can learn much that way, especially if you have never watched a fire closely. However, the wisest men watched fire for hundreds of years without finding out what really was going on. When scientists planned some careful experiments to test their ideas, they found out what really happens when materials burn. We shall do two experiments to get some facts about burning. Then we shall see how we can explain these facts.

EXPERIMENT 18. *What Happens to Magnesium When It Is Burned?* (*Pupil or teacher demonstration*) (*a*) Hold one end of a strip of magnesium ribbon in a pair of pliers. Have the other end pointing downward. Heat the lower end red hot with a match or burner. Observe as well as you can what happens. (The light of the burning magnesium is very bright. You may not want to look directly at it.) Compare the appearance of burned magnesium with unburned magnesium ribbon.

b) Get the lid from a small tin can. With a hammer and a nail make three holes in the edge of the lid, so that you can hang it up by three wires, as shown in Figure 128. Place the lid with its wires on one side of a balance. Put a level teaspoonful of magnesium powder (or two to three grams of broken magnesium ribbon) in the lid. Add weight to the other side of the balance until the two sides are exactly even. (Dry sand makes a convenient weight.) Hang the lid on a suitable support and heat the bottom with a flame until the magnesium begins to burn. Keep the can lid hot for at least five minutes so that all the magnesium will burn.

As the material cools, notice the color and general appear-

FIG. 128. Apparatus for Experiment 18b

ance of the burned magnesium. Be careful not to lose any of the material. Do you think that burning left the magnesium heavier, or lighter, or the same weight? When the lid is cool, put it back on the balance. Did burning change the weight of the magnesium? How do you know? How do you explain what happened? If you cannot explain what happened, keep the question in mind until you have done the next experiment.

EXPERIMENT 19. *What Happens to the Air in Which Iron Rusts?* (*a*) Wet the inside of a test-tube. Pour a spoonful of iron filings into the tube and shake it until the filings are sticking all over the inside of the tube. Turn the test-tube upside down in a glass of water. Place another test-tube containing no iron filings upside down in a glass of water (Figure 129).

How far does the water rise inside each test-tube? Why does it not rise farther? If something is taken out of the air when iron rusts, what will happen in one of the test-tubes? Why do we also use a test-tube without iron filings? Let the glasses and test-tubes stand for twenty-four hours.

b) After twenty-four hours examine both test-tubes. What has happened in each tube? How do you explain what you see? With cardboard, a cork, or your finger carefully cover the mouth of the test-tube containing the iron filings. Lift the test-tube out of the water and turn it over so that you keep the water in the test-tube. Light a splinter of wood. Remove the cover of the test-tube and quickly lower the splinter into the tube and hold it in the air above the water. What happens? Do the same with the tube containing no iron filings. What happens? How do you explain the difference in results?

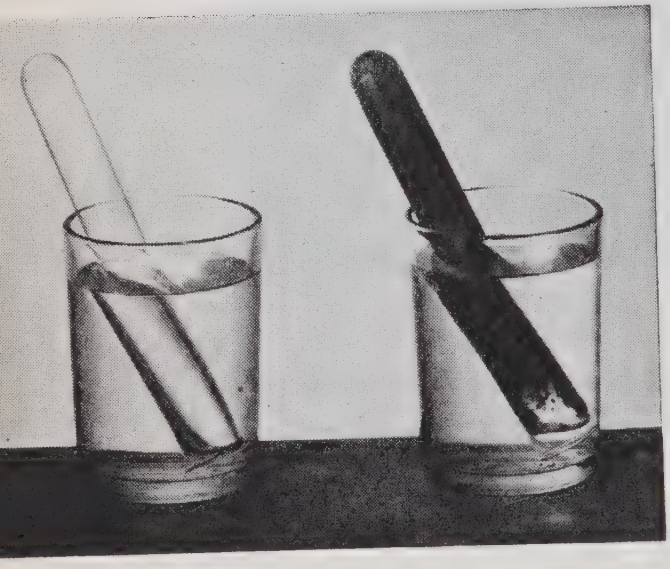


FIG. 129. Apparatus for Experiment 19a

Is the color of the iron filings the same as it was at the beginning of the experiment? Explain, if you can, what happened in the test-tube.

Your experiments have given you at least four very important facts: (1) When magnesium burns, its characteristics change. It is not the same material it was before. You know that this means a chemical change has taken place. (2) When magnesium burns, it gets heavier. (3) When iron rusts in air, some of the air disappears. (4) The part of the air that disappears when iron rusts is the part that is needed for burning. (The splinter would not burn in the tube with rusty iron filings in it.)

Now let us see how we can explain these four facts. Some invisible substance from the air must have joined with the magnesium while it was burning. That was what made the magnesium heavier. The rusting of the iron filings must have taken something out of the air.

That was what made the amount of air become less. If you had weighed the iron filings before they rusted and after they rusted, you would have found that the rusted filings were heavier. Like the magnesium, the filings joined with something from the air.

You probably know that the substance used from the air is called oxygen. It is one of the ninety-two elements that make up all the materials in the world. Careful experiments, somewhat like the one with the iron filings, show that about twenty-one per cent of the air is oxygen.

When oxygen from the air united with the magnesium, a new substance was formed. This new substance is a compound because it contains elements that have been united chemically. Compounds that contain oxygen and one other element are called *oxides*. The white compound of magnesium (Mg) and oxygen (O) that you made in Experiment 18 is magnesium oxide (MgO).

You can now write a chemical sentence, or *equation*, for the burning of magnesium.

MAGNESIUM (*a silvery metal*) and OXYGEN (*a colorless gas*) unite and form MAGNESIUM OXIDE. (*a white powder*)

You can also write an equation for rusting of iron.

IRON (*a silvery metal*) and OXYGEN (*a colorless gas*) unite and form IRON OXIDE. (*iron rust*)

The burning of magnesium and the rusting of iron are chemical changes. The materials combined or united

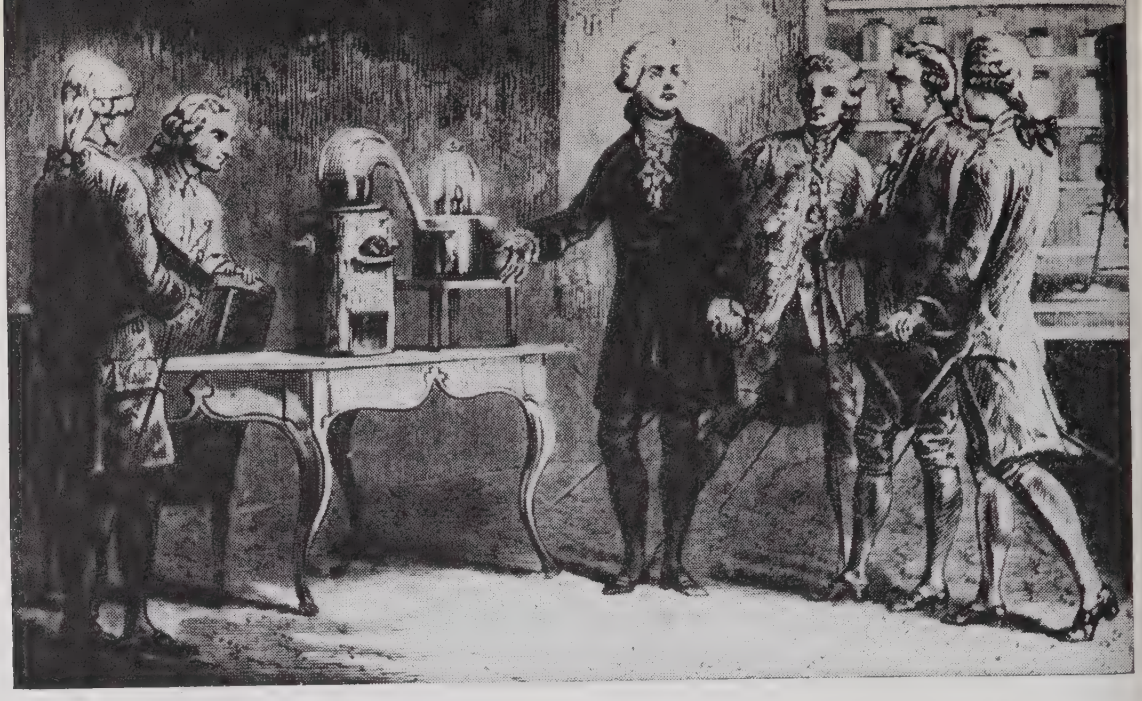


FIG. 130. Antoine Lavoisier, a French chemist who lived about 150 years ago, was the first person actually to prove that the oxygen in the air is the cause of all burning. In his experiments he found that mercury united with a certain amount of oxygen to form a red powder. When the red powder was heated, it gave up that same amount of oxygen.

with oxygen to make new substances. This kind of chemical change is called *oxidation*.

The burning of magnesium and the rusting of iron are both examples of oxidation. Why, then, is there heat and light in one case and not in the other? Let us first see about heat. When oxygen combines with a substance, heat is always produced. But some substances combine so slowly with oxygen that you cannot feel the heat. The part of the iron that is rusting gets warm when the iron combines with oxygen to make iron rust. But the iron and the oxygen are uniting so very slowly that the iron never gets hot enough for you to feel any change in temperature. Magnesium combines so rapidly with oxygen that great heat is produced in a short time.

Now, why do we sometimes get light when materials oxidize? And why is there sometimes no light when a material joins with oxygen? You have probably guessed

the answer. There is no light unless there is a great deal of heat. Iron joins so slowly with oxygen that there is not enough heat to make the iron glow. But touch a match to paper, and the paper unites so rapidly with the oxygen in the air that it bursts into a fire that gives off both heat and light. Materials must be very hot to give off light. They do not get hot enough when they join slowly with oxygen.

When oxidation takes place so rapidly that we can both feel heat and see light, we say that the material *burns*. When wood, paper, coal, gasoline, or gas combines with oxygen, heat and light are produced. We say that these materials burn. When iron combines with oxygen, we say that the iron rusts, or *oxidizes*. But, as you can see, burning and rusting are the same kind of chemical change. Oxygen unites with a substance in both cases and produces oxides.

Of course you know that many materials will not burn. Some of them will not combine with oxygen at all. Water, for example, will not unite with oxygen. Some materials will unit with oxygen but not fast enough to make light. When a material will burn, we say that it is *combustible*. We call it a *combustible material*. A material, such as glass, that will not burn, is said to be *incombustible*.

HOW DO OUR COMMON FUELS BURN? You found that magnesium was heavier after it was burned because oxygen had been joined to it. But when you burn wood or coal, the ashes that are left do not weigh as much as the wood or coal that you burned. And oil disappears entirely when we burn it. There seems to be a contradiction here. Where do these materials go when they burn?

Fig. 131. Exp. 20a Fig. 132. Apparatus for Experiment 20b

To find the answer to this question, we will study a burning candle. The wax of a candle is made of paraffin. Paraffin is a compound made of two elements, carbon and hydrogen. From what you have learned about burning, what compounds do you believe will be formed when the candle burns?

Experiment 20. *What Happens When a Candle Burns?* (*a*) Light the very tip of a candle wick. Watch to see what happens as the flame grows larger. What happens to the wax around the wick? Is the center of the candle flame light or dark? Hold a match stick horizontally across the flame just above the wick until it starts to burn (Figure 131). Remove it quickly from the flame and extinguish it. Examine the stick. Does the burning take place inside the candle flame or on the outside of the flame?

Blow out the candle and then quickly bring a lighted match to a point about one-half inch above the wick. What happens? Is the paraffin in a solid, liquid, or gaseous state when it burns? How do you know?

b) Light a candle. When the flame has grown to full size, hold a white dish in the yellow part of the flame. What

collects on the dish? It is carbon. Where did it come from?

c) Light a candle. Hold a cool, clean beaker, tumbler, or wide-mouthed bottle, mouth downward, over the flame for a short time. Do not let the flame touch the glass. What appears on the glass? Does it disappear when you hold the beaker away from the candle for a little while? Breathe into the beaker. Does your breath make a similar film? The film that the candle flame makes on the glass is composed of very tiny droplets of water (H_2O). Where do you think this water came from?

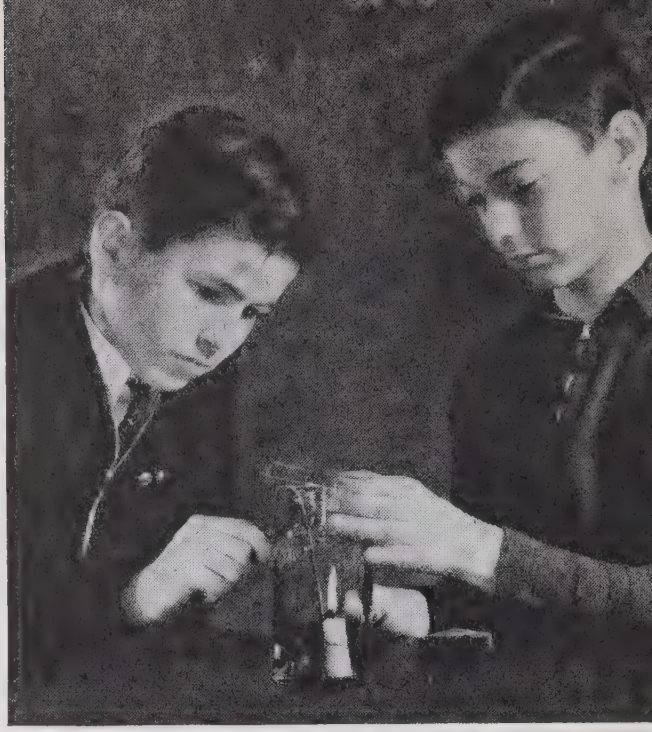


Fig. 133. Experiment 20c

d) Fasten a wire around a short piece of candle. Bend the wire to make the candle hang straight. Lower the lighted candle into a jar and cover the jar with a piece of glass. Remove the candle and quickly replace the cover. Pour in a little limewater and shake it up with the air in the bottle. Did the limewater turn milky in color? Carbon dioxide always makes limewater turn milky in color; thus limewater is a chemical test for carbon dioxide. Did the candle give off carbon dioxide?

Now let us explain what happens in the burning candle (Figure 134). Heat from the burning match melts the paraffin wax in the wick. Some of the wax changes to a gas because it is heated, and the gas unites with oxygen and burns. The heat from the burning gas melts the wax at the top of the candle. The melted paraffin travels up the wick in just the way that ink soaks through blotting paper. When it reaches the flame, the heat changes it to a gas. The paraffin compound becomes so hot that it breaks up into carbon and hydrogen.

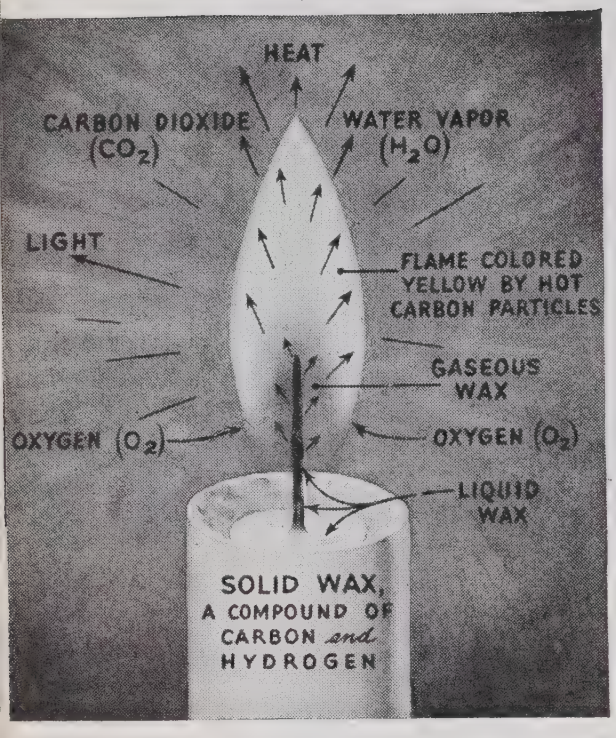


FIG. 134. A diagram of what happens when a candle burns

The carbon particles in the flame are so hot that they glow and give off a yellow light. When the particles reach the oxygen on the outside of the flame, they combine with oxygen and form carbon dioxide. The hydrogen combines with oxygen to form hydrogen oxide, or water. Since the temperature is very high, the water is in the form of water vapor. Both the carbon dioxide and the water vapor are colorless gases, and they mix with the air. Thus the candle gradually disappears.

We can now write three equations that will show what happens when a candle burns.

PARAFFIN WAX (*a solid white compound*) is separated into its elements, CARBON AND HYDROGEN.

CARBON (*a black solid*) and OXYGEN (*an invisible gas*) unite and form CARBON DIOXIDE. (*an invisible gas*)

HYDROGEN (*an invisible gas*) and OXYGEN (*an invisible gas*) unite and form WATER VAPOR. (*an invisible gas*)

If you understand what happens when a candle burns, you can understand what happens when any fuel burns. All of our fuels (oil, wood, coal, gas, etc.) contain compounds of carbon and hydrogen. Some also contain

carbon and minerals that are mixed with these compounds. When fuels burn, the carbon and hydrogen form carbon dioxide and water vapor; these mix with the air and disappear. The minerals do not combine with oxygen and are left as *ashes*.

You have just learned what happens when fuel is completely burned. But fuels are not always completely burned. Black smoke shows that some of the carbon did not burn. Often there is not enough oxygen to make all of the carbon burn. Sometimes the carbon is not heated enough to combine with oxygen. Usually smoke is produced when too much fuel is added. Some of the whitish or bluish smoke from fires is powdered ashes and other substances that do not change to invisible gases as the fuel burns.

FIG. 135. Sometimes we see black smoke pouring out from the chimneys of buildings and from locomotives.

Smoking fires have two great disadvantages. First, the carbon that does not burn is wasted. Every ton of *soot*, or unburned carbon, that goes up the chimney is a ton of fuel lost. Second, the soot itself is a nuisance. It darkens the sky, shuts out the healthful rays of the sun, and makes dirty places in which to live.

Sometimes when fuels burn where oxygen is not plentiful, carbon monoxide (CO) is formed, instead of carbon dioxide (CO_2). Carbon monoxide is a very poisonous gas. Some of it is formed when gasoline burns in an automobile motor. The gas then comes out

the exhaust pipe. That is why you must never stay in a closed garage while an automobile engine is running.

Self-Testing Exercises

1. Why does magnesium get heavier when it burns?
2. Do you believe that iron takes oxygen from the air when it rusts? Why?
3. In what ways are burning and rusting alike? In what ways are they different?
4. What two gases are formed in large amounts when fuels burn? Explain. How can you show that these gases are formed?
5. Why do fuels almost disappear as they burn? What substances in fuels do not burn?
6. What is burning?

Problems to Solve

1. Read again the story of the camp-fire on page 185. Explain as many of the italicized points as you can.
2. Explain how a flame is produced when wood burns.
3. Coke burns, but it sometimes burns without a flame. Why does it burn differently from coal?
4. A tea-kettle full of cold water will often become coated on the bottom with a film of water when placed over a lighted gas-burner. Explain where the water comes from.
5. Does the wire inside an electric-light bulb really burn when the bulb is turned on? Give reasons for your answer.
6. Can you get the gas out of the inside of a candle flame? Use a piece of glass tubing about four or five inches long, with a medium-sized opening ($\frac{3}{16}$ to $\frac{1}{4}$ inch). Wrap both ends of a wire around the tube to make a handle, or use a test-tube holder. Then hold it in a sloping position with the lower end just above the tip of the wick in a large candle flame. When a white cloud begins to come out the upper end of your tube, see if you can light it with a match or other flame.

Fig. 136. Many savage tribes know how to start fire by rubbing two things together. This can be done in several ways. A common way is to whirl a stick in the notch of a board until the wood powder that is made begins to glow. Some Boy Scouts can make fire by this plan in less than a minute.

Problem 2:

HOW DO WE MAKE FIRE?

How do we make things hot enough to burn? When you want to start a fire, you must do three things: (1) You must get some material that will burn—some combustible material. (2) You must see that a supply of oxygen reaches the combustible material. (3) You must heat the combustible material until it gets so hot that it begins to burn; that is, you must heat it to its *kindling temperature*. Whenever these three essentials are provided, a fire starts. Whenever one of them is lacking, the fire will not burn.

Let us see first how materials catch on fire. When you hold a lighted match to a piece of paper, the heat from the match raises the temperature of the paper to the point where it will combine rapidly with oxygen.

The paper bursts into flame. We use paper to start a fire because it is thin. Only a little heat is needed to raise it to its kindling temperature. The heat from the burning paper raises the temperature of the small sticks to their kindling point. These, in turn, heat the coal, or large pieces of wood, to the kindling point. You can see now why we start a fire in the way we do. We use materials with low kindling temperatures to heat materials with higher kindling temperatures.

In pioneer days the great problem in starting a fire was to get things hot enough to burn. You have read how the pioneers were always careful to have flint and steel and *tinder* in the tinder-box. Tinder was something that took fire very easily. To make it, they heated cotton or linen cloth in the oven until it was brown and ready to burn, or they shredded and dried the bark of certain trees. Then they put this tinder in a tin box to keep it perfectly dry. To make a fire they placed some tinder on the ground. Then they struck the piece of flint rock against the steel. The sparks that flew off set the tinder on fire. If a pioneer could not make fire with his flint and steel, he might have to carry an iron kettle for miles to "borrow fire" from a neighbor.

When chemists learned that they could get heat by mixing chemicals, they tried to find a quick, easy, and safe way of kindling fires. Many plans were tried before our modern matches were invented. The first matches were made in 1827.

The heads of matches have, at the very tip, a chemical called phosphorus sulphide. This chemical begins to burn at a rather low temperature. The rest of the match head contains (1) a chemical that gives off oxygen when

it is heated, (2) ground glass to increase friction, and (3) glue to hold the chemicals on the stick. When the tip is rubbed quickly over some rough surface, the friction makes the phosphorus sulphide hot enough to burn, and, with the help of the other chemicals, the stick is set on fire. Ordinary "strike-anywhere" matches are often set on fire accidentally. To prevent accidental fires safety-matches have part of the chemicals on the box or cover and part of them on the match. Thus a safety match will seldom take fire unless rubbed on the box.

FIG. 137. Safety matches were made with chlorine in a Vienna match factory early in the nineteenth century. This is the original package, which is in a German Museum.

Electricity can be used to make things hot enough to burn. Electric current sent through certain kinds of wires heats them red hot. Some cigar-lighters in automobiles work on this plan. Accidental fires are started rather often from the hot wires in electric irons and toasters. Electric sparks easily set fire to combustible gases. In an automobile motor each cylinder has a spark-plug. The spark-plug uses an electric spark to set the gasoline vapor on fire at the right time.

Sometimes combustible materials make themselves hot enough to burn. When this happens, we call it *spontaneous combustion*, or self-burning. How can this happen? One of the most common kinds of spontaneous combus-

tion takes place in rags that have been used to wipe up linseed (flaxseed) oil, or paint made from linseed oil. The oil unites slowly with oxygen from the air. This chemical change gives out heat. When the oil is spread out on the side of a house, the heat passes off into the air. But when the oil is inside a pile of rags, the heat is held in. The inside of the pile gets warm. The heat cannot escape; so the rags get warmer and warmer until they reach their kindling temperature. Then they burst into flame.

HOW DO FIRES GET OXYGEN? The second essential of fires is a supply of oxygen. As you know already, about one-fifth of the air is oxygen. This oxygen in the air supplies the oxygen for most fires. But what happens when all the oxygen in one part of the air has been used up? When a candle is put under a jar or inside a stoppered bottle, it soon goes out because it runs out of oxygen. Out in a room a candle never runs out of oxygen. Why does it not use all the oxygen around it and then go out?

Someone has said, "A fire provides its own supply of fresh air." You can easily see how this happens.

EXPERIMENT 21. *How Does a Fire Get Its Supply of Fresh Air?* Light a candle or a kerosene lamp. Hold a piece of smoldering punk above the flame and then below the flame. (If you have no punk, you may make *touch paper* by soaking filter paper or blotting-paper in a solution of potassium nitrate and then letting it dry. When it is lighted, it will smoke.) The smoke will show the direction of the air currents. Which way is the air around the flame moving? What makes the current of air? How does this movement help the fire get fresh air?

The experiment shows that there is a current of air upward about a fire. What makes this current of air? When the air next to the fire becomes hot, it expands and gets lighter. Then the heavier, cool air settles down, pushes the light air upward, and takes its place around the candle. Thus, fresh air is pushed into the fire, and the used air is pushed away. Of course, as the used air goes away, it takes with it the gases from the fire. When heavy, cold air settles down and pushes the lighter, warm air up, we say that the moving air makes *convection currents*.

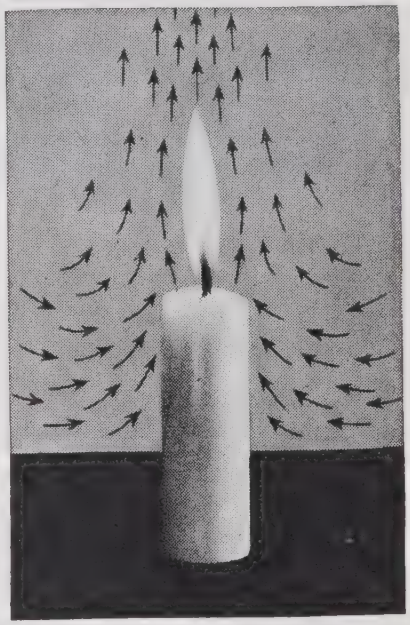


FIG. 138. The arrows show the movement of the convection currents of air around a burning candle.

We often speed up the convection currents so that our fires will get more oxygen and will thus burn more brightly. An experiment will show you how this is done.

EXPERIMENT 22. *Why Does a Chimney Help a Fire Burn Better?* Light a kerosene lamp, but do not put the glass chimney on. Notice how bright the flame is. Use the smoke from a burning punk stick or from a narrow strip of touch paper to see where the air currents are going into the burner.

Now turn up the wick of the lamp until it begins to smoke. It smokes because there is not enough oxygen going into the flame to burn all the carbon from the oil. Put on the chimney. What effect does the chimney have on the brightness of the flame? Does the flame stop smoking? Why? Test the air currents again.

The chimney of a kerosene lamp makes the lamp burn better because it separates the warm air above the flame from the cool air outside the chimney. Thus the convection current can move more rapidly, and the flame gets a better supply of oxygen. More oxygen makes the flame brighter because all the carbon can burn.

Our stoves and furnaces are also provided with chimneys to give the fires a better supply of oxygen. If you have ever tended such a fire, you know how the air rushes into the stove or furnace through the open doors. This movement of air up through a fire is called the *draft.* Chimneys also help us by carrying the smoke and sparks from fires high up into the air. In this way they protect us and our buildings from accidental fires.

Self-Testing Exercises

1. What three things are necessary in order to make a fire?
2. How would you build a camp-fire or a bonfire so as to be sure that the three necessary things are provided?
3. What are three different ways to make things hot enough to burn?
4. What is spontaneous combustion? How does spontaneous combustion start a fire?
5. How is a supply of oxygen brought to a bonfire?
6. What are two ways in which man helps his fires get a good supply of fresh air?
7. Give two reasons why we have chimneys in our homes.
8. Why will some matches strike anywhere, while others must be rubbed on the match box?

Problems to Solve

1. Light a candle and let the flame become large. Then blow out the flame and hold a lighted match about a half inch above the wick. Explain what happens.

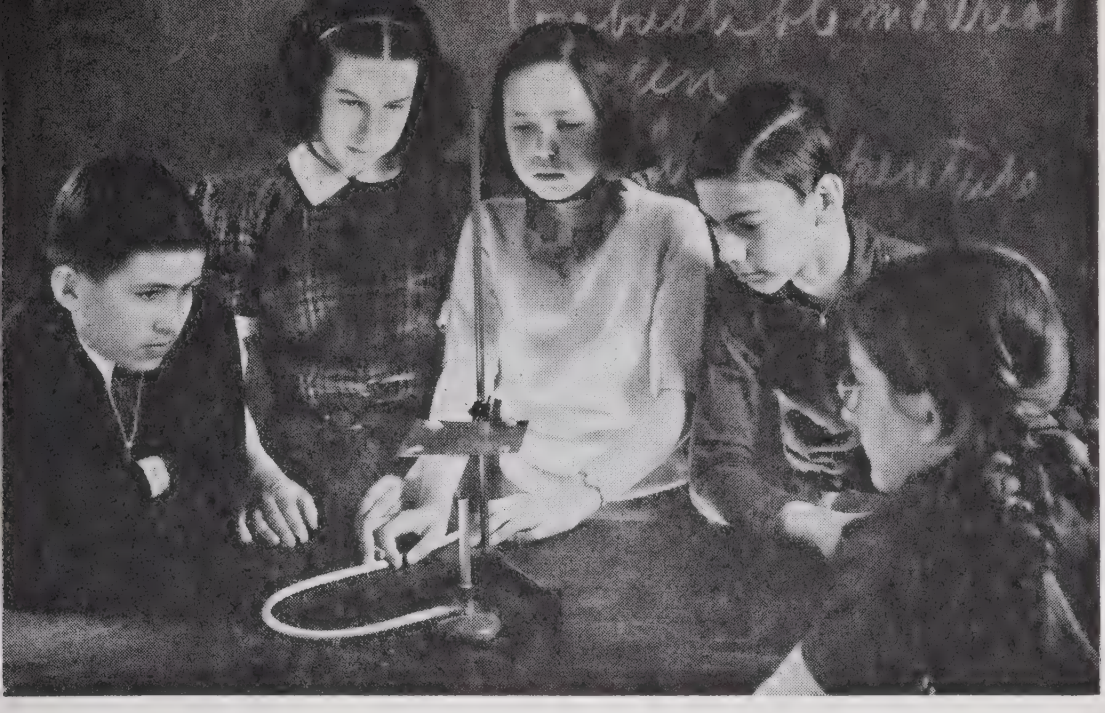


FIG. 139. Apparatus for Problem 5

2. When a large fire is burning, a wind is set up in the immediate vicinity. Explain.

3. Why does fanning a smoldering fire cause it to burst into flame?

4. How can a magnifying-glass be used to start a fire? Try to get a magnifying-glass and start a fire with it.

5. Test the kindling temperatures of sulphur, a match head, a piece of wood, and a piece of paper, as shown in Figure 139. Which has the lowest kindling temperature?

6. Borrow a friction cigar-lighter and see how it works.

HOW DO WE GET OUR IMPORTANT FUELS? The third essential of fire is something that will burn, that is, some combustible material. Of course, many substances that will burn cannot well be used to heat our homes. Combustible materials that are good for fuel must burn rather easily and give off large amounts of heat. We must also be able to get all of them we need without paying too much for them. Our common fuels are wood, coal, coke, gas, kerosene, gasoline, and petroleum. Table 6 gives the amounts of the different important fuels used in the United States in one year.

TABLE 6. IMPORTANT FUELS OF THE UNITED STATES

Fuel	Amount Used in 1936
Hard coal (anthracite coa)	54,760,000 tons
Soft coal (bituminous coa.)	434,070,000 tons
Coke	46,275,000 tons
Petroleum (crude oil)	1,098,516,000 barrels*
Gasoline (from petroleum)	515,485,000 barrels
Kerosene (from petroleum)	56,082,000 barrels
Natural gas	1,230,645,000,000 cubic feet
Manufactured gas	239,525,800,000 cubic feet

*A barrel of petroleum is 42 gallons.

Wood from trees was the first and easiest fuel to get. But in civilized countries much of the forest has been cut for lumber and to clear the land for farms. In large cities wood is usually more expensive than coal and thus is not often used. Other fuels, such as coal and oil, are better than wood because they give out more heat per pound than wood. We can get as much heat out of two pounds of coal as we can get out of three pounds of good wood.

Coal, as you know, is dug from the ground. There are two important kinds of coal: *bituminous*, or soft, coal, and *anthracite*, or hard, coal.

Bituminous coal is about fifty-four per cent pure carbon. About forty per cent of the carbon is combined with hydrogen, oxygen, nitrogen, and sulphur. When soft coal is heated in a fire, these compounds of carbon change to gases. These gases are not often completely burned, and a great deal of smoke is made. Soft coal is cheaper than hard coal and is the kind we usually burn in homes, factories, and locomotives.

Anthracite coal is about ninety-five per cent pure carbon and less than five per cent carbon compounds.

FIG. 140. Apparatus for Experiment 23

When it is heated, only a little gas is given off. Therefore, it burns with less smoke. It also burns more slowly than soft coal; therefore the fire needs less attention. People prefer anthracite coal for homes because it is not so dusty and because it burns more evenly.

Soft coal is important because we get coke and gas from it. You can make some coke and gas yourself.

EXPERIMENT 23. *How Are Coke and Gas Made from Soft Coal?* Fill a test-tube one-fourth full of crushed soft coal and fit it with a rubber or wet clay stopper and tube as shown in Figure 140. Heat the coal strongly with a burner. As soon as possible, light the gases that are given off by the coal. When no more gas is given off, let the test-tube cool. Then break the tube and examine the coke. (You can do this experiment at home by putting the coal in a coffee can that has a hole punched in the top. Heat the can on the gas stove, electric stove, or in a coal or wood fire. Be sure to burn the gases that are given off.)

Coke, as you can see, is almost pure carbon. It is rather hard to start it burning, but once started, it gives intense heat with practically no smoke. It is often mixed

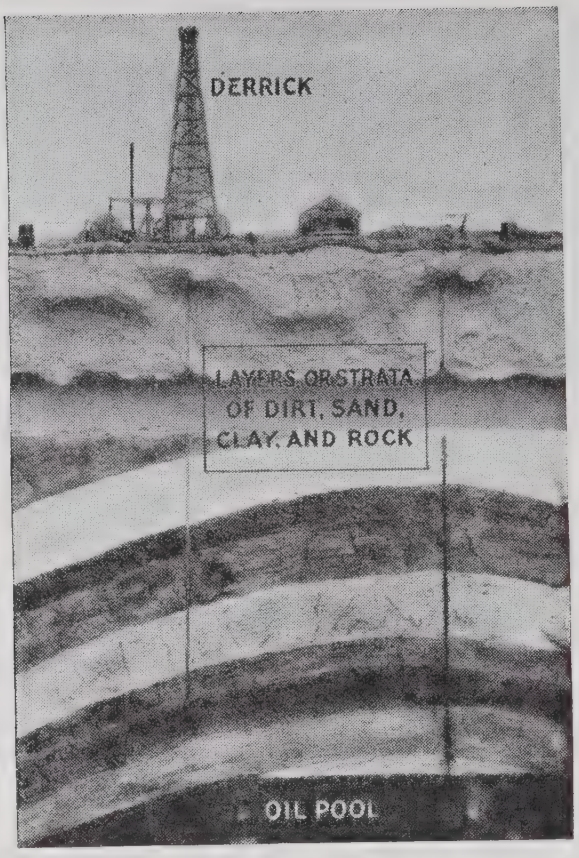


FIG. 141. Pools of oil are trapped hundreds of feet down under layers of rock and earth. The oil is taken from the ground by drilling holes through the rock and earth.

with soft coal in furnaces. The coal burns more easily than the coke, and thus keeps the coke burning. The gas obtained from heating soft coal contains many impurities. These impurities are removed before the gas is sent through pipes to our houses.

Next to coal mines, oil wells and gas wells are our most important sources of fuel. Oil from oil wells is called *petroleum* or *crude oil*. Petroleum is a black, bad-smelling liquid which is a mixture of many different compounds of carbon and hydrogen. Each compound has its own boiling and condensing temperature (see pp. 126 and 131).

To separate these compounds the crude oil is heated in large *stills* in factories called *oil refineries*. The compound that evaporates easiest soon changes to a vapor. This vapor is lead into a pipe where it is cooled and condensed back to a liquid. The oil is then heated to a higher temperature until the next compound changes to a gas and so on. Gasoline comes off first, and then kerosene. From petroleum we also get oil for our automobile engines, paraffin, and oil to burn in furnaces.

Above the petroleum in oil wells, and in some places

FIG. 142. From the wells the crude oil goes to oil refineries. The refineries may be near the oil fields or hundreds of miles away. Some of the oil rides in tank-cars on a railroad, but much of it goes through underground pipe lines. In the picture a section of a pipe line is being laid in the ground.

where no oil is found, drillers strike natural gas. In parts of our country where natural gas is plentiful, it is used as a fuel for heating, lighting, and power. In recent years natural gas has been piped for thousands of miles to the larger cities.

Self-Testing Exercises

1. Not all combustible materials are used for fuel. Why?
2. Make a table with three columns. In the first column make a list of the natural fuels and below that make a list of the manufactured fuels. In the second column write opposite each fuel one of its advantages, or good characteristics. In the third column give a disadvantage of each fuel.
3. Describe briefly how coal gas is made.
4. Where is natural gas found? What is it used for?
5. How do we get gasoline and kerosene from crude oil? Which of these two is more important? How do you know?

Problems to Solve

1. What fuel is used to heat your home? What are the reasons for using that fuel?
2. Interview a coal dealer. Find out about different kinds

FIG. 143. We regulate open fires by the amount of fuel we put on them and by the way we arrange the fuel. The boy in this picture is arranging the sticks of wood so that the currents of air can pass up through the wood to carry plenty of oxygen to the burning fuel.

of coal. Which kind of coal do you believe to be the best for use in your own home?

3. Early in the morning when people are refueling their fires, you often see much black smoke coming out of the chimneys. What is the probable cause of this? How can it be prevented?

4. If gas is manufactured in your community, visit the plant and report in class on the manufacture of gas.

5. Find out what scientists mean by the *fuel value* of a fuel. Which has the greater fuel value, wood or hard coal or soft coal?

Problem 3:

HOW DO WE REGULATE FIRE?

A FIRE that we cannot control does very little good. It may run wild and destroy many things, or it may burn so slowly that it does not give us the heat that we need. Sometimes we want to keep a fire from getting started or to stop it if it gets started. In Problem 4 you will study how destructive fires are put out. In this problem you will learn how the fires that we use in our homes and factories are made to burn the way we want them to burn.

In Problem 2 you learned that a fire must have three things: oxygen, some material that will burn, and heat enough to start the burning. If any one of these is

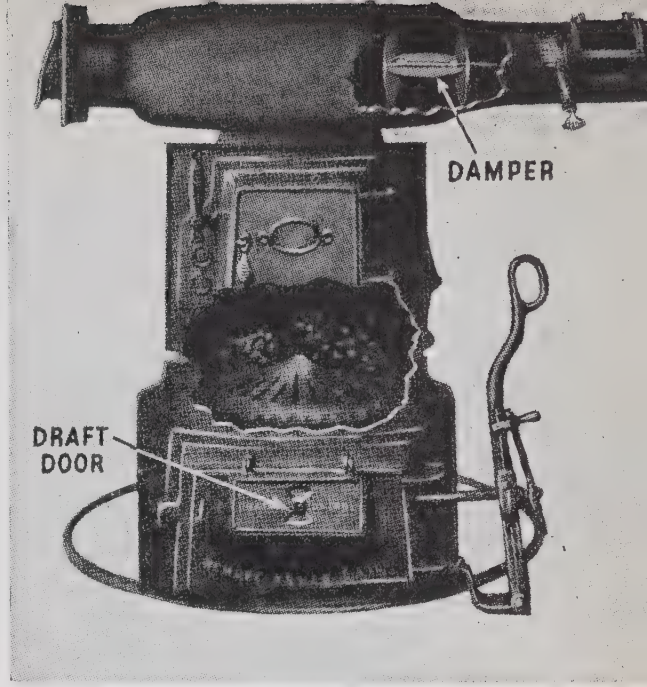


FIG. 144. This view of a furnace shows the damper and the draft door. Part of the furnace is cut away to show the grate that holds the fuel. To make a hot fire, should the draft door be open or closed? Should the damper be open or closed? Why?

lacking, no fire will ever start. If you take away any one of these, a fire will stop burning. If you can regulate the supply of oxygen or the supply of fuel, or both, a fire will burn as rapidly or as slowly as you wish. Let us see how we regulate our many different kinds of fires.

HOW DO WE REGULATE THE FIRES IN STOVES AND FURNACES? After man had used open fires for thousands of years, he learned that he could get more of the heat from the fire if the fire were inclosed in some kind of unburnable box. So he made an iron fire-box and called it a stove. When he made the fire-box large enough to heat a whole building and placed it in the basement, he had a furnace. Fire in stoves or furnaces heats buildings with less fuel than we would need to use in open fires. This is true for two reasons. First, the fire-box with its chimneys and pipes helps keep the heat from escaping into the outdoors. Second, furnaces and stoves are so made that we can regulate the supply of oxygen to make the fire burn the way we want it to.

Of course, any stove or furnace must have a pipe and a chimney to carry away the gases and smoke. The pipe usually is connected to the top of the stove. Near the bottom of the stove, below the *grates* that hold the fuel, we find another opening. This opening is closed

by a *draft door*. The draft door is arranged so that we can open it as much as we wish or close it entirely. In the pipe leading to the chimney we find a *damper*. This is used to open and close the pipe. When we start a fire, we open the damper in the pipe. We also open the draft door. Thus there is a free passage of air coming in at the bottom of the stove, passing up through the fire and out the pipe to the chimney.

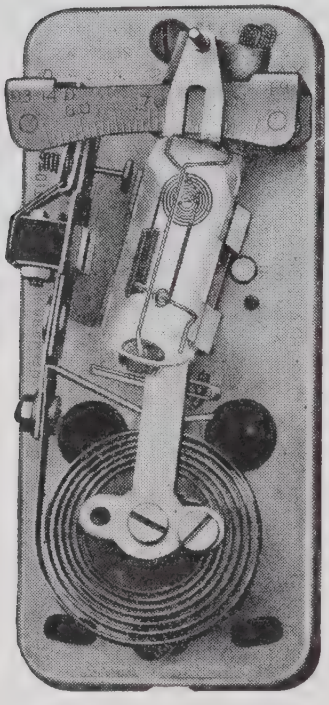


FIG. 145. In a thermostat the expansion and contraction of the metal coil turns the electric current on or off.

If the draft is strong, it makes the fire burn rapidly. By opening or closing the drafts and the damper just the right amount, we can make the fire burn as rapidly or as slowly as we wish. After the fire is well started, we close the draft door so that the rush of air will not carry so much heat up the chimney. We can also regulate the oxygen supply by the amount of fuel we put on the fire. Too much fuel chokes a fire because the air cannot pass through the fuel and give it oxygen. Ashes on top of the grates also keep the air from getting to the fire.

Many modern furnaces have an electric motor that opens and closes the drafts after the fire is started. In the rooms heated by the furnace is a *thermostat*. This device is a kind of metal thermometer. When the room is warm enough, the thermometer makes two pieces of metal touch. An electric current then runs the electric motor just long enough to close the drafts. Later, when

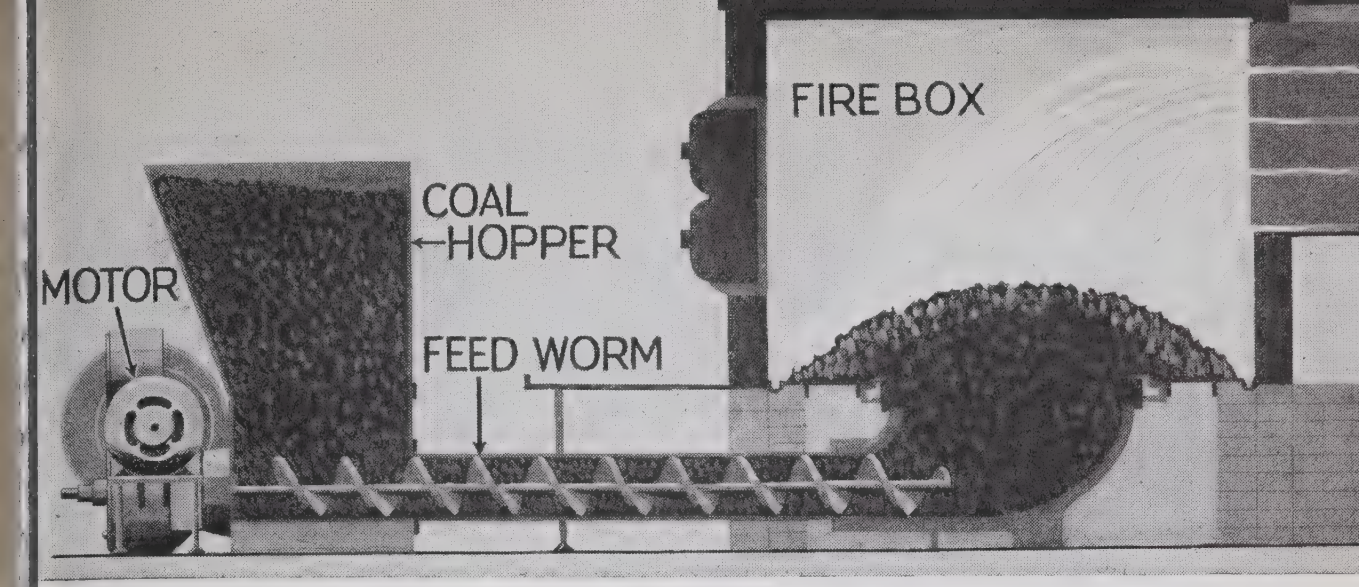


FIG. 146. In an electric stoker the coal is placed in a hopper, and a long screw, called a *feed worm*, run by an electric motor pushes the coal from the hopper through a tube and up into the fire. At the same time a fan blows air into the fire to help it burn better. The motor is turned on and off by a thermostat. The person who takes care of the fire has only to fill up the coal hopper once in a while and take the ashes out of the furnace.

the room gets cool again, the thermometer makes two other pieces of metal touch, and the motor opens the drafts. When the thermostat is set right and the fire is properly built, the furnace may need no attention for several hours.

A coal furnace is even more easily regulated when the coal is fed in by a machine called a *stoker*, as shown in Figure 146. One great advantage of electric stokers is that they feed the fresh coal into the bottom of the fire instead of on top. When coal is put on top of a fire, much gas passes off unburned before the coal gets hot enough to make the gases burn. But when the coal is fed in beneath the fire, the gases are heated very hot as they go up through the hot coals. By the time they get up to the fire, they are so hot that they combine easily and quickly with oxygen; therefore, they burn more completely. Since the gases are more completely burned, there is hardly any smoke.

HOW DO WE REGULATE THE FIRE IN A KEROSENE STOVE? Most kerosene-burners are made much like kerosene lamps (Figure 147). Oil comes to the bottom of each burner through a pipe. A woven cotton wick in the form of a hollow cylinder dips into the oil and passes up into the burner. The oil enters the wick and soaks through to the top. The wick can be moved up or down so that more or less of it is at the top of the burner. The kerosene, when heated, evaporates from the part of the wick above the burner. Thus by turning the wick up or down, you can regulate the amount of kerosene that will evaporate and burn.

The chimney of a kerosene-burner makes a good draft like any other chimney. Openings on both sides of the wick send strong currents of fresh air into the burner. This large supply of air quickly burns the fuel and makes a hot, blue flame instead of the yellow flame of the kerosene lamp.

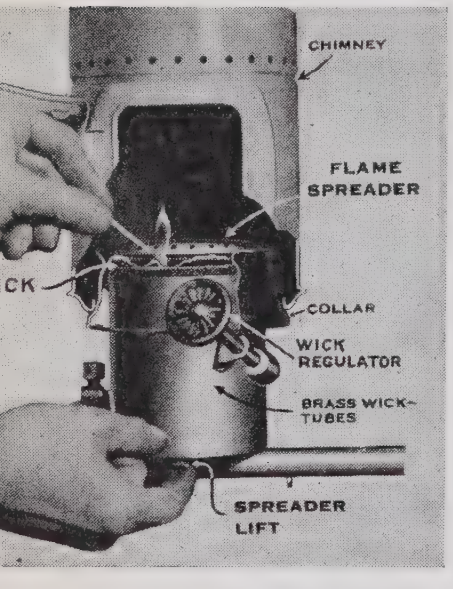


FIG. 147. The parts of a kerosene-stove burner

HOW ARE GAS-BURNERS REGULATED? Most gas-burners work like a burner invented about seventy years ago by a German scientist named Robert Bunsen. Let us see how a Bunsen burner works.

EXPERIMENT 24. *How Does a Bunsen Burner Work?* (*a*) Take a Bunsen burner apart by unscrewing the barrel. Find a little hole through which the gas comes. Connect the bottom part of the burner to a gas-jet with a rubber tube. Turn on the gas just a little and light the stream of gas that comes out through the small opening. What color is the flame? Turn on the full pressure of the gas. What happens?

b) Shut off the burner and put the parts together. Turn on the gas and light it at the top of the barrel. Open and close the holes at the bottom. How does mixing air with the gas change the color of the flame? Can you explain why the color changes?

c) Find out what part of the flame is hottest. To do this, get a piece of iron-screen wire or a wire gauze used to put under flasks while they are heating. Light your burner and close the holes. Put the screen into the bottom of the yellow flame. Move it very slowly up through the flame. Watch the color of the wires. What is the hottest color they show? Where do they show this color?

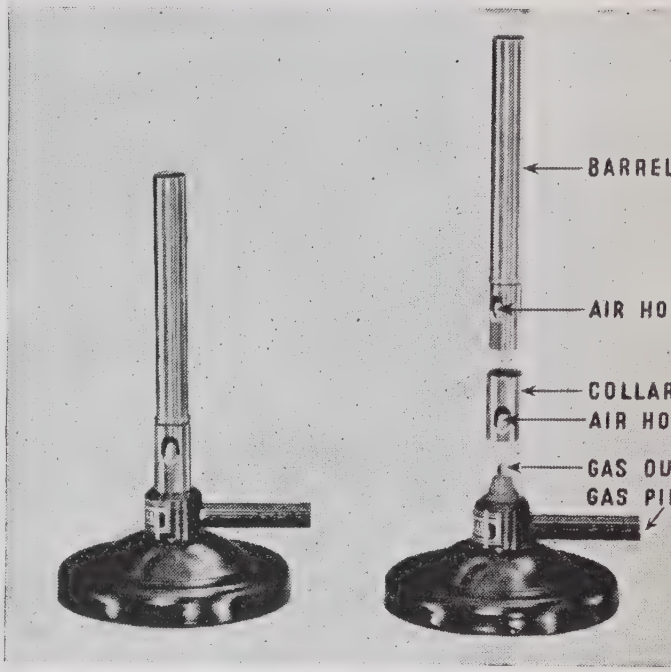


FIG. 148. Experiment 24

Now make the flame blue and repeat the test with the wire screen. In which flame do the wires become hotter? Is there more gas burning in the hotter flame? What causes the difference? Which flame would you use to melt a glass tube? Where in the flame would you hold the tube?

d) Turn the gas down to make a medium-sized yellow flame. Hold a white dish in the upper part of the flame. The black material you get on the dish is carbon. Try a clean dish in the blue flame. Do you get carbon on it? Why?

Your experiments show that we get the cleanest and hottest gas flame when we mix the right amount of air with the gas before we burn it. If you look at the burners in a kitchen gas stove, you will find that they are arranged almost exactly like our laboratory burners.

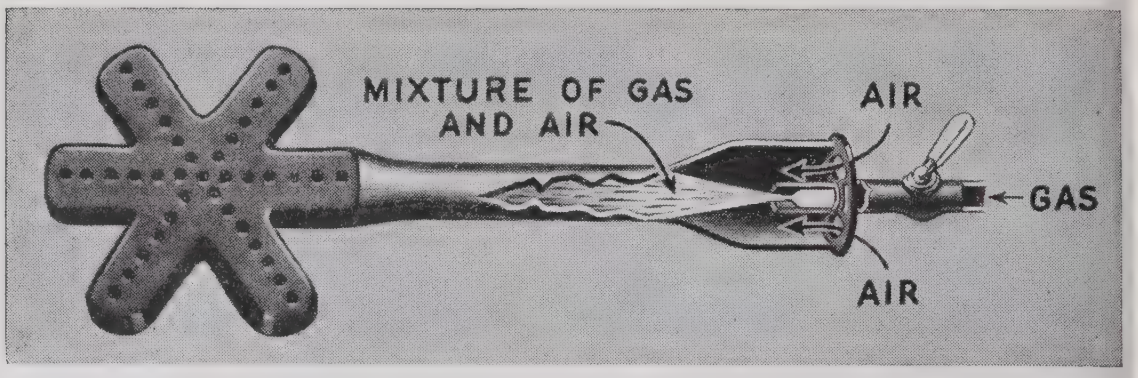


FIG. 149. In a kitchen gas-stove burner the gas enters through the gas line and is mixed with air in the mixing chamber.

If you take a burner apart, you will find a small hole at the end of the pipe where the gas comes in. Around this is a large pipe with openings to let in air. These openings have shutters that can be turned to let in just the right amount of air. If you have a gas-burner at home, light it and notice the color of the flames.

HOW ARE THE FIRES IN OIL-BURNING FURNACES REGULATED? To burn oil without smoke, the oil must first be changed into a very fine mist, or vapor. One common way of doing this is to pump the oil through a tiny nozzle under high pressure. This breaks the oil into a fine mist (Figure 150). At the same time an electric fan blows a current of air past the nozzle. An electric spark sets the mixture of fuel and air on fire, and it burns until a thermostat stops the motor that runs the pump and fan.

Another kind of oil-burner has a plate, or disk, in the center of the furnace (Figure 151). An electric motor whirls the disk at high speed. The oil comes up into the disk and is thrown outward against the sides of the furnace, where it burns. The whirling disk also acts like a fan to bring a stream of air into the furnace.

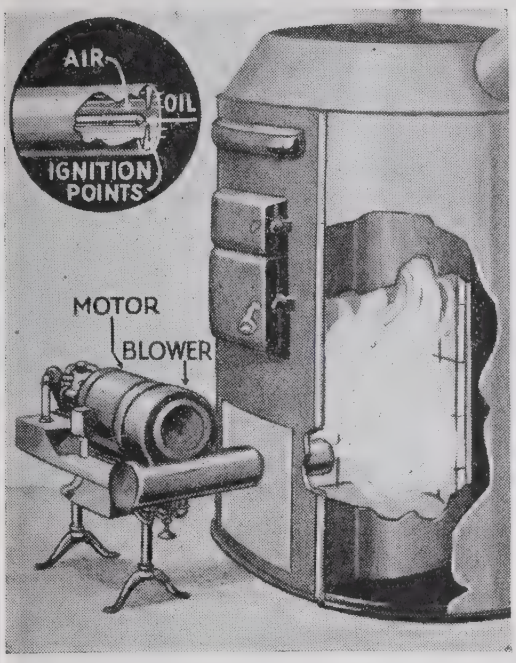


FIG. 150. This is called a gun-type oil-burner. In the upper left-hand corner is shown the construction of the nozzle for spraying the oil and air.

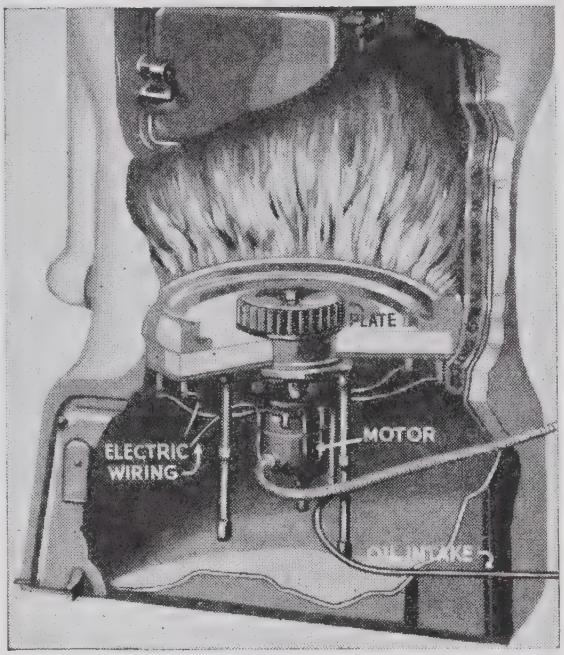


FIG. 151. A rotary-atomizer type of oil-burner throws oil and air against the sides of the furnace where it is set on fire by an electric spark.

Self-Testing Exercises

1. Explain in one or two sentences how fires are regulated.
2. What kinds of heating devices are used in homes? How is each one regulated? Explain carefully.
3. Compare the regulation of a coal fire with the regulation of a gas fire.

Problems to Solve

1. If the cost of fuels were the same for the amount of heat secured, what kind of fuel would you prefer to use? Give your reasons.
2. Find automatic coal-stokers and oil-burners on display in stores. Learn how they work.
3. Make a drawing of the furnace in your home, labeling all of its parts. Some furnaces may be regulated from upstairs

FIG. 152. There is a familiar saying, "Fire is a good servant but a bad master." Without fire to do work for man there would have been little progress in the world. But every year in our country $250,000,000 worth of property and 10,000 human lives are lost in fires. Yet three out of four fires could have been prevented if someone had been careful.

by means of a chain. If your furnace is regulated in this fashion, explain how the chain operates the regulating devices.

4. If you have a gas stove in your home, make a drawing of the burner. Show the control valve, air holes, mixing chamber, and places where the gas burns. If your stove has an automatic lighter, explain how it operates.

5. Explain why the construction of an oil-burner must be different from that of a gas-burner.

Problem 4:

HOW DO WE PREVENT AND EXTINGUISH ACCIDENTAL FIRES?

FOR THE last twenty years the United States has averaged one accidental fire every minute. Think of it! Every time the minute-hand of your clock passes a mark on the dial, a fire starts—sixty every hour, more than 1400 every day. Homes and schools and churches, factories and stores, forests and wild life are going up in smoke. Carelessness or ignorance on the part of someone

causes most of the fires that destroy lives and property. Many things are being done to stop this terrible loss from fire. The use of building materials that will not burn, greater care, and better ways of fighting fires have helped reduce the loss to one-half what it was in 1926. Table 7 gives the most common causes of the fires that need never happen.

TABLE 7. Causes of Preventable Fires

1. Careless Handling of Fire and Fire Materials
   - Throwing lighted matches on combustible materials.
   - Allowing trash piles to accumulate.
   - Dumping ashes that contain live coals.
   - Overheating stoves.
   - Burning out of chimneys containing much soot.
   - Rolling up oily rags (spontaneous combustion).
   - Storing coal where little air circulates (spontaneous combustion).
   - Storing damp hay (spontaneous combustion).
   - Lighting matches in a garage.
   - Bringing lighted matches near gasoline tanks.
   - Using gasoline or benzene to clean clothes.
   - Filling kerosene or gasoline lamps while using a lamp for light.
   - Placing a lamp or a lantern where it can be upset easily.
   - Starting fires in stoves with kerosene or gasoline.

2. Electricity
   - Driving nails into electric wires and causing "short-circuits."
   - Using wrong kind of fuse for the kind of circuit.
   - Attaching too many electrical devices at the same time.
   - Using wires too small for a heavy current.
   - Rubbing the insulation off wires.
   - Wiring buildings without proper insulation.

3 Faulty Construction of Heating Devices and Buildings
   - Defective oil stoves.
   - Leaking gasoline tanks.
   - Stoves placed over wood or carpets.
   - Fireplaces without screens.
   - Poorly constructed flues and chimneys.
   - Running pipes near combustible materials.
   - Improper closing of openings between rooms and corridors.
   - Using combustible materials for buildings.

HOW ARE ACCIDENTAL FIRES PREVENTED? Each cause of a fire in Table 7 did one thing: it allowed some combustible material to get too hot. As you know, wherever there is air, there is oxygen. Therefore, there is danger of fire whenever we let combustible material get next to something hot and whenever we put something hot on a combustible material.

The first important way of preventing fires is to keep fire and hot objects away from combustible materials. All ashes should be put in metal cans or in brick or concrete bins. Ashes often have live coals in them. All lighted cigars and cigarettes should be laid on metal, porcelain, or glass. Fires should be built only on soil, metal, stone, or brick. Buildings that are close to each other should be built only of fireproof materials. Waste paper and rubbish should never be stored near furnaces or stoves.

FIG. 153. One should *never* use gasoline, benzene, naphtha, or alcohol near a fire, as this woman is doing.

Electric wires should be properly connected, so that they will not overheat, and covered, so that they do not touch combustible materials. Never pour kerosene on a smoldering fire. Never use lighted matches or candles when you are trying to find gas or gasoline leaks. Flashlights are inexpensive and safe.

FIG. 154. Grass fires are often checked by plowing the grass on a strip around the burning area.

Spontaneous combustion, in which chemical action produces heat, is a more common cause of fire than most people suppose. Each year fires started in this way cause losses of about $12,000,000. The most frequent cause of spontaneous combustion is the storing of oily rags, mops, or other materials. As you learned on page 200, such oils slowly oxidize and heat the materials enough to start them burning. Other fires are started by the spontaneous heating of sawdust, grain, charcoal, soft coal, raw wool, and hay. Materials that are likely to heat should not be stored in large masses unless they are so well ventilated that the heat can escape.

HOW DO WE EXTINGUISH FIRE? In spite of our care some accidental fires will get started. Thus, everyone should be ready for action. If you live in a town or city, be sure that you know how to send a fire-alarm. If a fire starts that you cannot stop, you should call for help immediately.

What you have learned about fire should help you to put out fire or to keep it from spreading. A fire that you cannot put out may often be slowed down and kept in

FIG. 155. A carbon-dioxide fire extinguisher

one room for a time by shutting doors and windows. This shuts off some of the oxygen and keeps the hot gases from spreading the fire rapidly. Smothering a fire, that is, shutting off the air, is usually the most practical way of stopping it. Woolen rugs, blankets, and coats burn slowly and may be thrown on a small fire or wrapped around a person whose clothing has caught fire.

Water and the steam it produces will smother a fire. Water also cools things until they will not burn. But water is worse than useless on gasoline and oil. These materials float on the water and are spread by water without being extinguished. For small gasoline or oil fires use sand, dirt, or woolen materials.

Cutting off the supply of fuel is, of course, another way of stopping a fire. Quick action to shut off gas or flowing gasoline is often necessary to prevent serious fires. Forest fires are sometimes fought by clearing a space ahead of the fire or by starting small "backfires" that may be kept under control while they burn a strip around the main fire. In cities the firemen sometimes dynamite buildings to stop fire from spreading

HOW DO CHEMICAL FIRE EXTINGUISHERS WORK? You will often see small hand fire extinguishers ready for use in buildings or other places. You should know how they work, so that you can use them more quickly and

effectively. A kind of chemical extinguisher we often see in school buildings is a brass tank hung on the wall (Figure 155). Attached to the top of the tank is a rubber hose with a nozzle. The directions on the side read something like this: "To start, turn bottom up."

This kind of extinguisher is really just a tank of water with chemicals kept separate from the water. When it is turned upside down, chemical action makes the water squirt from the hose. An experiment will show you how this kind of extinguisher works.

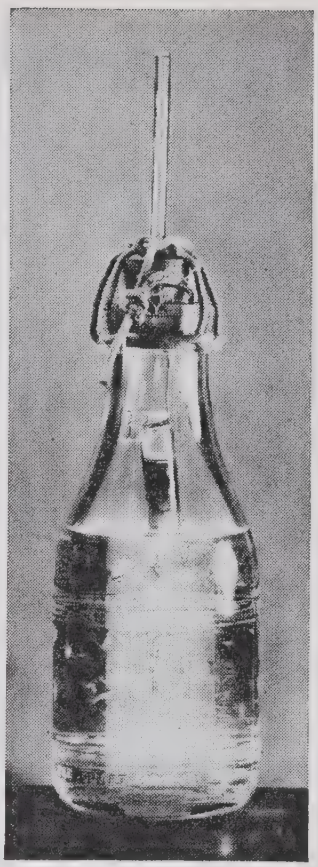


FIG. 156. Experiment 25b

EXPERIMENT 25. *How Does Chemical Action Push the Water Out of an Extinguisher?* (*a*) Put some water in the bottom of a jar. Dissolve about as much baking-soda (sodium bicarbonate) in the water as it will hold. Now pour some vinegar or dilute sulphuric acid into the soda solution. What happens? The gas that is formed is carbon dioxide. Lower a burning candle into the jar. Explain the results,

b) *Teacher Demonstration.* Arrange a milk bottle or other wide-mouthed bottle as shown in Figure 156. Put a strong solution of baking soda in the large bottle, and a 50 per cent solution of sulphuric acid in the small bottle. *Wire the stopper in securely.* Then turn the bottle upside down over a sink or bucket. (*Caution:* Do not get the solution on your clothes.)

If you wish, attach a rubber tube with a glass nozzle and start a small fire in a sink or outdoors. Then put out the fire with the model extinguisher. Why does the water squirt out of the extinguisher?

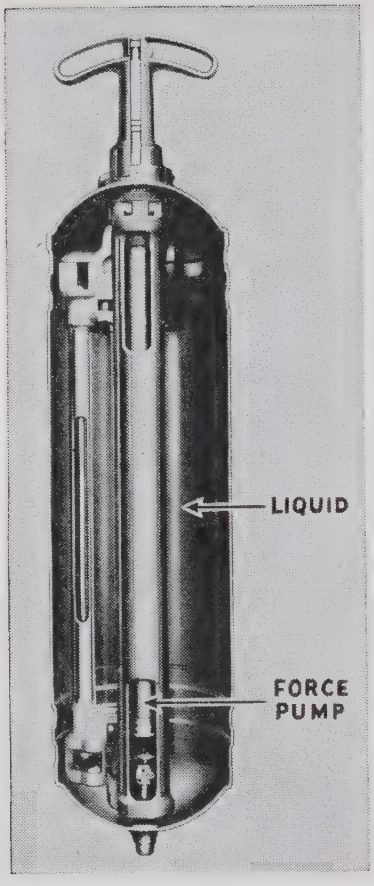


FIG. 157. Inside the carbon-tetrachloride extinguisher is a pump that forces out the liquid when the handle is worked up and down.

The carbon-dioxide extinguisher is nearly full of a solution of baking-soda. A bottle in the top of the tank contains concentrated sulphuric acid. A lead stopper fits loosely in the bottle. When the tank is turned upside down, the stopper falls out, and the acid mixes with the soda solution. A chemical action immediately makes a large amount of carbon dioxide. This gas forces the water out through the hose.

Another common kind of extinguisher is smaller than the carbon-dioxide extinguisher, and the directions tell you to work it like a pump (Figure 157). This kind of extinguisher usually contains a liquid called carbon tetrachloride, or a mixture of carbon tetrachloride with something else.

EXPERIMENT 26. *How Does Carbon Tetrachloride Put Out a Fire?* (*a*) Pour two or three tablespoonfuls of carbon tetrachloride (or "Carbona" cleaning fluid) into a deep pan. Cover the pan loosely for ten minutes to allow part of the liquid to evaporate. Set a short lighted candle in a large beaker. Pour the vapor (not the liquid) from the pan into the beaker. Explain why the candle goes out. Try to light the candle again without taking it out of the beaker.

b) *Teacher Demonstration.* Set a small dish of gasoline or kerosene in a large flat pan. If you have some asbestos, put

it under the pan. Light the gasoline or kerosene. Pour water on the burning gasoline until the dish "runs over." What happens? Now pour some carbon tetrachloride on the burning gasoline. Why does the fire go out?

This experiment shows you how carbon-tetrachloride vapor puts out a gasoline or oil fire. Carbon tetrachloride changes to a vapor quickly when heated. This vapor is very much heavier than air. Therefore, when carbon tetrachloride is squirted on a fire, the heavy vapor settles down over the burning material and keeps the air away long enough to stop the fire. Extinguishers that use this chemical are small and easily carried in trucks and automobiles. Furthermore, the liquid will not freeze in cold weather.

Another kind of extinguisher that is valuable for oil fires pours or throws a foam on the fire. This foam is made of bubbles of carbon dioxide. The foam of carbon dioxide bubbles floats on the gasoline or oil and keeps the air away. The foam is made by mixing a solution of baking-soda and extract of licorice root with a solution of aluminum sulphate. The carbon dioxide is formed by chemical action between the soda and alumi-

FIG. 158. This man is putting out an oil fire with a carbon-dioxide extinguisher. He is directing the extinguisher to the point where the burning is taking place rather than on the flames above.

Fig. 159. An important part of the fire-fighting equipment in large river, lake, and seaport towns is the fire boat. It is a tug with fire pumps that pump from 3000 to 12,000 gallons of water a minute.

num sulphate. The extract of licorice root helps make tough bubbles.

You may see other kinds of extinguishers. If they are near where you study, work, or play, be sure to read the directions on them. You will then know how to use them in case of fire.

In buying extinguishers, roofing materials, oil-burners, and electrical devices, you should look for a label that says these devices have been tested and approved by the Underwriters Laboratories. These laboratories are supported by fire-insurance companies, and their label shows that the inspected material is safe and reliable for preventing or extinguishing fires.

Self-Testing Exercises

1. From Table 7 make a list of the ways you think a fire might get started in your own home. Opposite each item in your list tell how a fire from that cause can be prevented.

2. Find all the devices for extinguishing or fighting fire in your school. Make a list of the different devices.

3. Explain how a carbon-dioxide fire extinguisher puts out a fire. Tell why the water comes out and why it puts out a fire.

4. How does a carbon-tetrachloride extinguisher put out a fire? Why is it better than water for a gasoline fire?

5. If a fire started and the extinguisher you used did not put it out, what would you do?

6. If a fire started where there were no extinguishers, what are the things you might do?

Problems to Solve

1. What are the most common causes of fires in your city or neighborhood? Decide how you can get the information, and then get it.

2. Find out how the fire department in your city or town is equipped to fight fire. Firemen are usually glad to explain about their apparatus.

3. What are some of the reasons why fires are often very hard to put out?

4. Read again the story of the camp-fire on page 185. See if you can explain each italicized phrase.

LOOKING BACK AT UNIT SIX—SUMMARY EXERCISES

1. In this unit you have learned some more science principles that you can use to explain everyday problems. Make a list of them, writing them as sentences.

2. Show that you know the meaning of the following words:

carbon dioxide	*charcoal*	*oxidation*	*tinder*
kindling temperature	*combustible*	*thermostat*	*oxide*
spontaneous combustion			

ADDITIONAL EXERCISES

1. Make a study of how to prevent loss from fire. You can get much helpful material by writing to the National Board of Fire Underwriters, 85 John Street, New York, or 222 West Adams Street, Chicago.

2. Light a Bunsen burner and bring an iron or copper screen down on the flame. Why does the flame not go through the

screen? Turn out the burner. Then turn on the gas, hold the screen above the burner, and bring a lighted match to the gas above the screen. What happens? Can you explain it?

3. Read in reference books about peat and lignite. What are they, and what are they used for?

4. If a kerosene lamp begins to smoke, how do you think the smoking could be stopped?

5. Collect samples of the different kinds of fuels sold in your community. Compare their characteristics. If possible, find out their heat value and see which kinds one should buy to get the most heat for the least money.

6. Study the photo-flash bulbs used by photographers. The bulbs are filled with pure oxygen. What is the combustible material? How is it "set off"? What is the white material inside the glass after the bulb has been used?

7. How can a city reduce the amount of smoke from the chimneys of its homes, factories, and office buildings? If your city has a "smoke-abatement" department, learn what it is doing.

8. Pails of sand are sometimes kept in garages and chemical laboratories. What is the use of the sand?

9. Why do you blow on a match to put it out and blow on a smoldering fire to make it burn?

10. Why do factories with large steam power-plants often have tall chimneys?

11. Why does dry wood burn more easily than wet wood?

12. Make a class collection of newspaper clippings about fires. Group the fires according to causes and keep a record of the lives lost and the property destroyed whenever this information is given.

13. About how many cubic feet of oxygen are there in your schoolroom?

FIG. 160. Magnets have many uses. Here two magnets are carrying scrap iron from railroad cars to a Great Lakes freighter. So powerful are these magnets that bars of steel weighing ten tons may be lifted, carried, and dropped with speed and safety. Although the magnets lift great weights, the men who run them only pull a lever. In this unit you will learn about different kinds of magnets and how they help us.

UNIT SEVEN

UNIT 7

HOW DO MAGNETS WORK?

INTRODUCTORY EXERCISES

1. Ten statements are given below. Some are true; others are false. Write the letters *a* to *j* in a column. After each letter write the word *true* or *false* according to whether that statement is true or false.

a) Magnets attract iron and steel.

b) Some magnets attract things because the magnets are shaped like horseshoes.

c) Both ends of a magnet have power to attract.

d) A magnet made of iron keeps its magnetism longer than a magnet made of steel.

e) Magnets attract iron and steel only when these substances touch the magnet.

f) Magnets attract iron and steel through glass.

g) When two magnets near each other are allowed to move freely, their north poles attract each other.

h) One can destroy the magnetism of a magnet by rubbing it with a piece of steel.

i) The earth acts like a huge magnet.

j) When a magnet is allowed to swing freely, it always points north and south.

2. Answer as many of these questions as you can.

a) Would it be unwise for you to leave a watch lying near a strong magnet? Why?

b) Why are magnets sometimes made in the form of horseshoes?

c) What is lodestone?

d) How is an electromagnet like a permanent magnet? How is it different?

e) What are some of the different uses of magnets?

FIG. 161. Many different stories are told about the discovery of brown rock that would attract pieces of iron to it. One story is that a young shepherd, named Magnes, discovered the rock when he touched the iron tip of his shepherd's staff to such a rock. When he tried to pick up his staff, he had to pull hard to get it away from the rock. But no one really knows how magnetism was discovered.

LOOKING AHEAD TO UNIT SEVEN

ALMOST everyone has used a *magnet* to pick up needles, tacks, and other things made of iron and steel. Perhaps you have made boats that move when a magnet is brought near them, or you may have used magnets to perform tricks. The kind of magnet you use is probably a straight bar of metal or a strip of metal shaped like a horseshoe. Magnets of this kind have been made for many years, but long before they were used, men knew about this strange force called *magnetism*.

We do not know just when and how magnetism was discovered. Many thousands of years ago men had learned of a certain kind of stone, found in the ground, which would attract pieces of iron. An ancient legend tells of a wonderful magnetic mountain near the sea. When ships tried to sail past this mountain, its magnetism drew the iron nails from the ships, and they fell apart.

Soldiers wearing iron armor were drawn against the mountain. The magnetism of the mountain held them fast, and they died.

There is another legend of a certain ruler who told his people that his body would rise after his death. To make this happen, he had a huge piece of magnetic stone fastened in the top of the temple. His coffin was made with an iron lid. During the funeral ceremony the attendants let the coffin go, and the stone drew it to the top of the temple. Of course, we do not believe these stories, but they show that magnetism was known thousands of years ago.

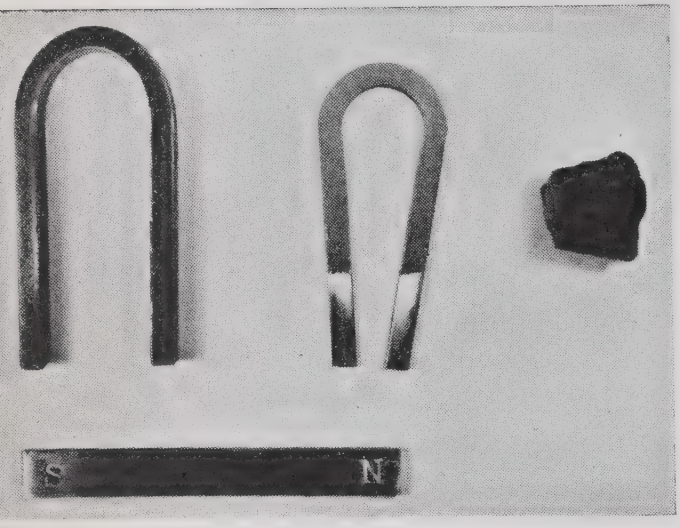


FIG. 162. You will use these different magnets in your experiments. The top row shows a U-magnet, a horseshoe magnet, and a piece of lodestone. Beneath them is a bar magnet.

Thousands of years ago someone discovered that a piece of iron would act like a magnet if it was rubbed on a magnetic stone. Then another strange discovery was made. If the piece of iron was floated on a piece of wood in a bowl of water, the iron would point in a north-south direction. This was the first compass used to tell directions. Because the magnetic stone could be used to show direction, it was called *lodestone*, which means leading stone. Scientists have found that it is a kind of iron ore. They call it *magnetite*.

For hundreds of years people thought that magnetism was nothing but a strange kind of power that some metals had. It was interesting, but it was not of any

real use to them. Scientists knew that magnetism was a kind of force, but the magnets they were able to make could move only small pieces of iron. They could not imagine how such a small force could be made useful except to tell directions.

Finally men learned how to use electric currents to make magnets that were very strong. And they learned how the magnets made with electricity could be turned on or off as they wished. Then magnets could be used in many ways. From that time to this, men have been learning more about magnets and more ways of using them. In this unit you will learn many of the things scientists have discovered about magnets and the ways they are used.

Problem 1:
WHAT WILL A MAGNET DO?

WHAT MATERIALS ARE PULLED BY A MAGNET? You know that magnetism is a kind of force; that is, it will pull things. You cannot see the force; you cannot feel the force; and you cannot hear it. But you know it is there because you can see what it does. To begin your discoveries about this strange force, you will first need to find whether the force will pull all kinds of materials, or whether it will pull some materials and not others.

EXPERIMENT 27. *What Will Magnets Pick Up?* Get as many different kinds of small objects as you can: tacks, paper clips, a penny, a dime, a nickel, silk, wool, a pencil eraser, a piece of chalk, pins, pen points, a gold ring, some air-rifle shot, a piece of celluloid. On a sheet of paper make two columns, one headed "Objects Attracted by Magnets," and the other

"Objects Not Attracted by Magnets." With a lodestone or steel magnet or both touch the first object and see if the magnet picks it up or attracts it at all. Write the name of that object in the column where it should be.

If you used both the lodestone and the steel magnet in the experiment, you discovered that they both attracted the same things: nails, tacks, needles, pen points, and other objects made of iron and steel. Thus we say that iron and steel are *magnetic substances.*

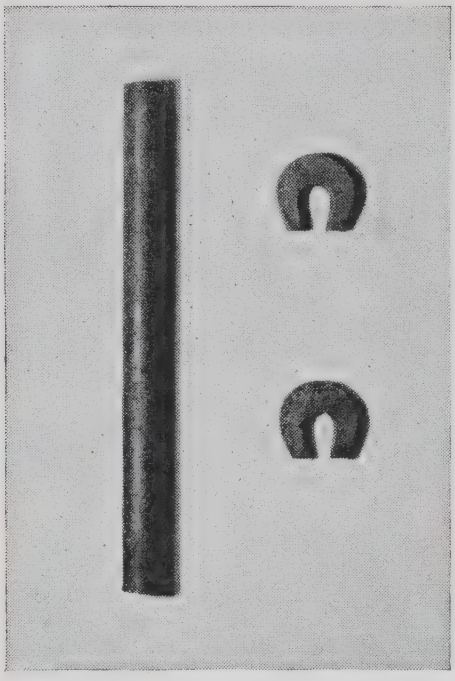


FIG. 163. These magnets are made of mixtures of metals. The rod magnet is made of steel containing cobalt and chromium. The small magnets are alnico.

A few other substances are magnetic, for example, pure nickel and pure cobalt. Perhaps this statement seems wrong to you. In the experiment you found that a "nickel" five-cent piece was not attracted by the magnet. A five-cent piece, however, is not pure nickel. It contains more copper than nickel, and, as you found, a copper penny is not attracted by magnets. Pure nickel and pure cobalt are not often used to make things. They are usually mixed with copper, tin, or some other metal.

Not long ago some chemists accidentally discovered a mixture of aluminum, nickel, and cobalt which is very magnetic. They named it *alnico* (Figure 163). It is used to make very strong magnets. For some reason, alnico magnets will lift much heavier objects than iron mag-

nets of the same size will lift. However, we may still say that iron and steel are the most important magnetic substances.

From what you have learned you can put substances into two groups: (1) those that are attracted by magnets, called *magnetic substances;* (2) those that are not attracted by magnets, called *non-magnetic substances.* As you see, there are many more non-magnetic substances than there are magnetic substances.

Self-Testing Exercises

1. How can you tell whether a substance is magnetic or not?
2. Name substances that are magnetic.
3. What is a magnet? (Begin your definition in this way, "A magnet is.....")
4. From the list below select the names of the things that are attracted by magnets and write them in one column. In another column write the names of those that are not attracted by magnets.

pencil leads	a steel marble	a steel needle
an iron ring	a strip of copper	a rubber band
bits of paper	a compass needle	a piece of wood
iron filings	a glass marble	an iron nail

Problems to Solve

1. Tell why a magnet will pick up some common pins and not others, even though the pins may all look alike.
2. Tiny slivers of metal are sometimes removed from workmen's eyes with a powerful magnet. One day a piece of metal flew into a workman's eye. A magnet would not pull it out. Why do you think the magnet did not work?
3. A story was once told of a thief who stole money from people's pockets with a magnet. Give a reason for believing or not believing this story.

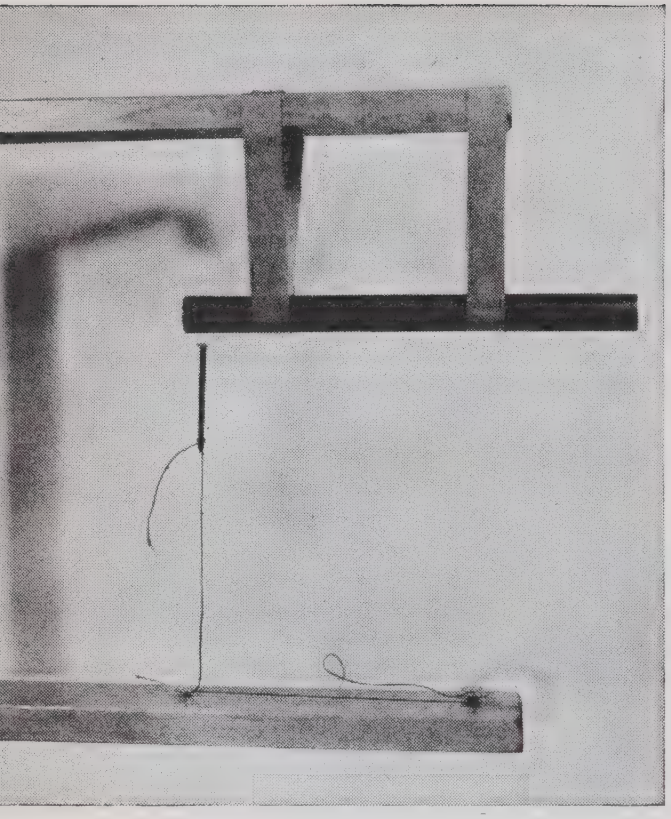


FIG. 164. Apparatus for Problem 6

4. If you will touch a magnet to a "tin" can, you will find that it is attracted. What does this show you about a "tin" can?

5. Does a piece of iron attract a magnet just as truly as the magnet attracts the iron? Plan an experiment to prove your answer.

6. How can a nail be made to float in the air? Fasten a very strong magnet about twelve inches above a table by means of a clamp, or paper stirrups hung on a wooden frame, as shown in Figure 164.

Fasten the end of a thread about a small nail just above its point. Drive a tack in the tabletop or in the lower part of the frame directly under one end of the magnet. Fasten the other end of the thread to the tack. Have the thread long enough to allow the head of the nail to reach within one-eighth inch of the magnet.

Lift the head of the nail as near to one end of the magnet as the thread will allow. The force of the magnet will cause the nail to remain suspended in the air. Fasten heavier objects to the string to see what size load the magnet will hold.

7. A boy had a piece of cork. He put it on a piece of paper and then moved a magnet under the paper. The cork followed the magnet. How do you suppose the boy made the cork move?

DO ALL PARTS OF A MAGNET ATTRACT WITH EQUAL FORCE? If you study Figures 165 and 166, you can probably tell whether all parts of a magnet pull with an equal amount of force. But you will want to experiment

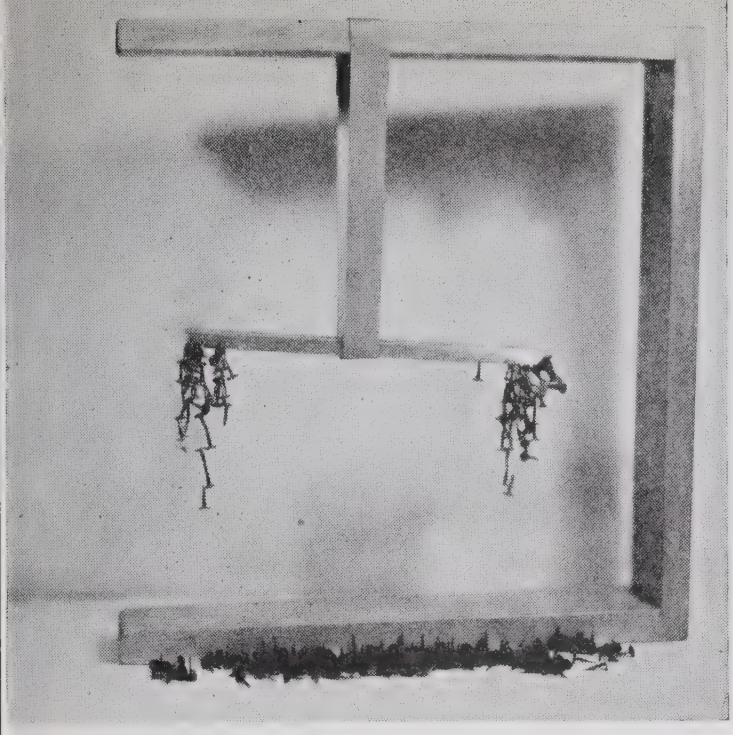


FIG. 165. Apparatus for Experiment 28a

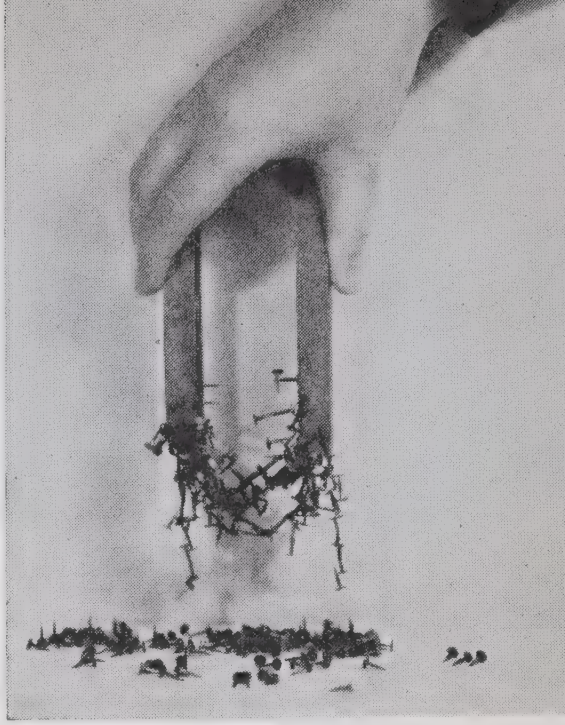


FIG. 166. Exp. 28b

for yourself to test your idea to be sure you are right. Experiment 28 will help you discover one of the most important things about the force of magnets.

EXPERIMENT 28. *What Parts of a Magnet Have the Greatest Pulling Power?* (*a*) Spread a box of iron carpet tacks thickly and evenly upon a sheet of paper. Lay a bar magnet flat upon the tacks and lift it gently so that the tacks will not be jarred loose. To what parts of the magnet do most of the tacks cling?

b) Do the experiment again, using a horseshoe magnet. Be sure to lay the magnet flat on the tacks before lifting it. How are the bar magnet and the horseshoe magnet alike in the way that the tacks cling to them?

c) Test all parts of a piece of lodestone with tacks. Does the magnetism of the lodestone seem to be stronger in some places than in others? What do these experiments show?

In Experiment 28 you saw that most of the tacks stuck to the ends of the magnets. This shows us that the ends of magnets have much more force than the other parts of magnets. We call these ends of the magnet its *poles*.

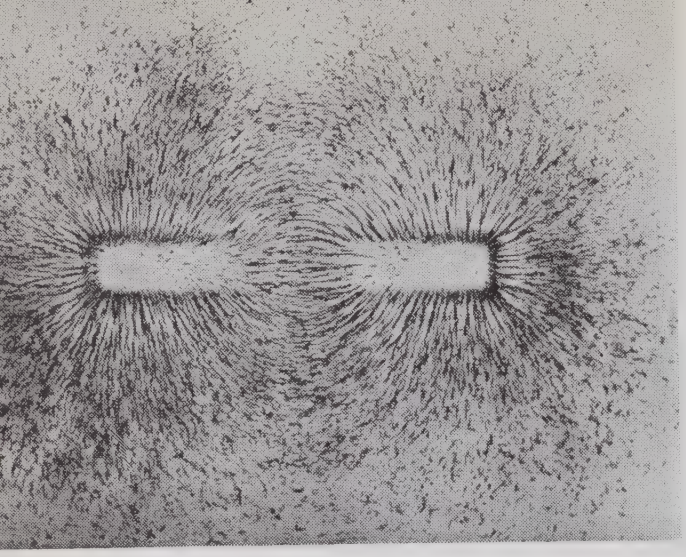


Fig. 167. Experiment 29a

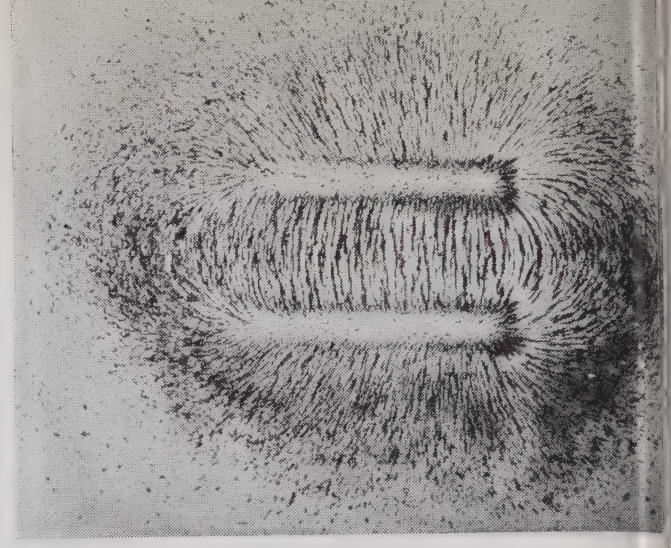


Fig. 168. Experiment 29b

The poles are the spots on the magnet where the force is strongest.

While playing with magnets, you have probably amused yourself by seeing how far away a magnet would cause a tack to move toward it. The force of the magnet reaches out from the magnet. This space in which the force pulls is called the *field of force* of the magnet; it is also called the *magnetic field*. You can see where this magnetic field is by doing the following experiment.

Experiment 29. *What Is the Field of Force of a Magnet?* (*a*) Place a sheet of stiff paper over a bar magnet. Sprinkle some iron filings evenly on the paper. Tap the paper gently as you sprinkle the filings. What happens? Look carefully at the pattern made by the filings.

b) Do the experiment again, using first a horseshoe magnet and then a piece of lodestone instead of the bar magnet. See how far from the magnets the iron filings are attracted in each case. Are the patterns made by the filings around the bar magnet like the patterns around the horseshoe magnet and the lodestone? Around what parts of the magnets are the lines of iron filings closest together?

Your experiment has shown you that the force of a magnet reaches out from the poles in all directions. In order to see more clearly the shape of magnetic fields,

look at Figures 167 and 168. The patterns made by the filings are shown as a series of lines. Each of these lines is called a *line of force.* Notice that the lines of force pass through the space around the magnets from one pole to the other. When iron filings are dropped into the field of force of a magnet, they arrange themselves along the lines of force.

You can see that the lines of force are closest together at the poles of the magnet, because the magnetic force is strongest at the poles. If a stronger magnet is used, the lines of force will be even closer together, and you can see the pattern farther from the magnet. You might like to do Experiment 29 over again with both strong magnets and weak magnets to see what different patterns the lines of force make.

Self-Testing Exercises

1. Do lines of force go out in all directions from the poles of a magnet or are they in a flat sheet like the paper on which you sprinkled the iron filings? From the experiments you have done and from the pictures in this problem, prove that your answer is correct.

2. What does anyone mean when he says a magnet has poles?

3. Close your book and draw a picture showing how the lines of force are arranged in a magnetic field.

Problems to Solve

1. From what you have learned in this problem, how would you answer this question: "Will the force of a magnet pass through some kinds of materials?"

2. If you can get some blue-print paper, make blue-prints of magnetic fields. You will have to do most of the work in a closet or some room that is nearly dark. Lay a magnet upon

a board or a large book. Place a piece of blue-print paper upon the magnet and sprinkle some iron filings upon the paper. Tap the paper to arrange the filings. Hold the paper in bright sunlight for about a minute.

Now go back into the dark room and pour the iron filings off the paper. Soak the paper in cold water for several minutes. Then place it on a flat surface to dry. You should have a clear blue-and-white picture of a magnetic field. Try several prints with bar and horseshoe magnets in different positions.

3. Does a lodestone have poles like a steel magnet? How do you know?

CAN THE FORCE OF A MAGNET PASS THROUGH SUBSTANCES? You have seen that there is a field of force around each magnet and that magnetic substances in the field are attracted by the magnet. Suppose that something else is placed between the magnet and the magnetic substance. Will the force of the magnet be stopped, or will it pass through the material?

In Experiment 29 you saw that the force of the magnet passed through paper. Will the force pass through other materials?

EXPERIMENT 30. *Can a Magnet Attract Iron Through Substances?* (*a*) Sprinkle some iron filings upon a sheet of stiff paper. Hold one end of a strong bar magnet under the paper. Do not let the magnet and the paper touch. Keep them about one-half inch apart. What happens to the filings?

Move the magnet around under the paper, but do not let the paper and the magnet touch. Do the filings follow the magnet? Can a magnet attract iron filings when it is not touching them? Now touch the magnet to the under side of the paper. Move the magnet about. What happens to the filings?

FIG. 169. The force of this strong magnet makes the iron filings stand on end even though the force has to pass through the glass plate that rests on the magnet.

b) Do part *a* again, using glass, sheets of zinc, copper, brass, aluminum, and thin wood.

c) Do part *a* again, using a thin sheet of iron. Through what kind of substances does the force of a magnet pass? What kinds of substances stop the force of a magnet?

When a magnet comes near iron filings, they stand on end. If the magnet is strong enough, the filings try to follow it as if they were alive. It is strange to see filings stand on end, much as the hair stands on end upon a dog's back when he is angry. And it is still more strange to see that magnets attract through substances like paper, glass, zinc, copper, brass, aluminum, and thin wood. Why do these things happen? It is because the field of force of a magnet will pass through the paper, glass, and other substances. A magnet causes iron filings to form a pattern on the other side of sheets of non-magnetic substances.

But will magnets attract through all substances? As you saw when you used a thin sheet of iron, no pattern of the magnetic field was formed on the side away from the magnet. Careful experiments show that when a sheet of magnetic material, like iron, is used, the lines of force from one pole of a magnet pass first into the iron. They follow the iron to a place near the other pole of the magnet. Then they pass back to the magnet. In

this way a sheet of magnetic material acts like a screen and keeps a magnet from attracting iron and steel objects on the other side of the sheet.

Suppose you worked in a factory where very powerful magnets were used. How could you protect the steel spring of your watch from being affected by the magnets? You could use an iron case for the watch instead of a gold case. The iron case would act like a magnetic screen and draw the lines of force of the magnetic field into it. Then the steel spring would not be harmed.

Self-Testing Exercises

1. Through what kinds of substances will the force of a magnet pass? How can you show that your answer is true?

2. Through what kinds of substances will the force of a magnet not pass? How can you show that your answer is true?

3. How can you prevent magnetic force from reaching an object? Give an example to show that this knowledge is sometimes useful.

Problems to Solve

1. When they are not in use, horseshoe magnets are usually stored with "keepers"; that is, the magnets have strips of iron placed over the poles. Will a magnet pick up magnetic materials as well if the "keeper" is left on? Explain.

2. (*a*) With a piece of paper and filings show the shape of the field around a horseshoe magnet when its "keeper" (or a piece of iron) is about an inch away from the poles.

b) Do the same as above, but use a piece of brass or copper instead of the keeper.

3. Some radio tubes are easily affected by the magnetism of near-by objects. Why do you suppose that these tubes have can-shaped covers? Of what material would you expect the covers to be made?

FIG. 170. This boy has learned how to magnetize his knife blade. He is showing his friends that he can pick up nails and needles with it. Do you know how he magnetized the knife blade?

Problem 2:

HOW CAN WE MAKE MAGNETS?

HOW CAN WE MAKE IRON AND STEEL ACT LIKE MAGNETS? If you will do the following experiment, you will find out how the boy in Figure 170 magnetized the knife blade, that is, made a magnet of it.

EXPERIMENT 31. *How Can We Magnetize a Piece of Steel?* (*a*) Dip a large needle (or piece of clock spring) into iron filings. Do the filings stick to it? Stroke the needle with a pole of a lodestone. Be sure to move the lodestone in the same direction for each stroke. Again test the needle with iron filings. What has happened to it?

b) Repeat part *a*. This time use a pole of a bar magnet. Stroke in the same direction each time. Does the needle become magnetized?

c) Wrap at least 200 turns of small cotton-covered or enamel-covered wire around a cardboard tube about one-half inch in diameter. Test a thin piece of steel, such as a knitting

needle, to see how many tacks it will pick up, if any. Then place the steel inside the tube. Connect the ends of the wire around the tube to a dry-cell. Strike the steel several times with a hammer. Disconnect one end of the wire from the dry cell and take the steel out. See how many tacks the steel will now pick up. What has happened to it?

FIG. 171. Experiment 31c

You see from this experiment that you can magnetize a piece of steel by stroking it with a magnet or by passing a current of electricity through a wire wrapped around it. The magnets that you buy are made by the latter method, but a much stronger current of electricity is sent through the coil of wire as the magnets are being made.

Iron can be magnetized just as easily as steel, but it will not keep its magnetism. That is why the magnets you buy are made of steel. You might try magnetizing a piece of iron and a piece of steel at the same time by using the coil of wire you made for Experiment 31. If you will dip the ends of the steel and iron in iron filings while the current is on, you will find that both will pick up about the same amount. If there is any difference, the steel will pick up less. When the current is turned off, however, you will find that the steel will be able to lift many more filings than the iron.

Because steel holds its magnetism for a long time, it is used to make *permanent magnets.* Iron, on the other hand, is used to make *temporary magnets.* You can see now why the magnets we buy are made of steel.

In order for steel magnets to keep their strength, they ıust be handled carefully. Let us see what happens hen we jar a magnet.

Experiment 32. *What Effect Does Pounding Have upon he Strength of a Magnet?* Magnetize a knitting needle. See ow many tacks it will hold up. Then lay the needle on a oard and pound it with a hammer. Again see how many acks it will hold. What did the pounding do to the needle's nagnetism?

You can see now why it would not be wise to drop a nagnet. Every little jar tends to make the magnetism eaker. While you would probably never think of heating a magnet in a flame, you might be interested to know hat heat also will weaken a magnet. Can you think f an experiment to show that this is true?

elf-Testing Exercises

1. What are two ways of magnetizing a piece of steel?
2. Why is steel used to make magnets?
3. What is the difference between a permanent magnet and temporary magnet?

roblems to Solve

1. You can buy a tack hammer that will help you keep from itting your fingers. All you have to do is to place a tack n the head of the hammer and drive it in. What do you uppose has been done to the head of the hammer?
2. Is the head of the hammer made of iron or steel? How o you know?
3. Suppose you have two bars exactly alike in appearance.)ne is made of iron, and the other is made of steel. How ould you use magnetism to decide which one is made of teel?

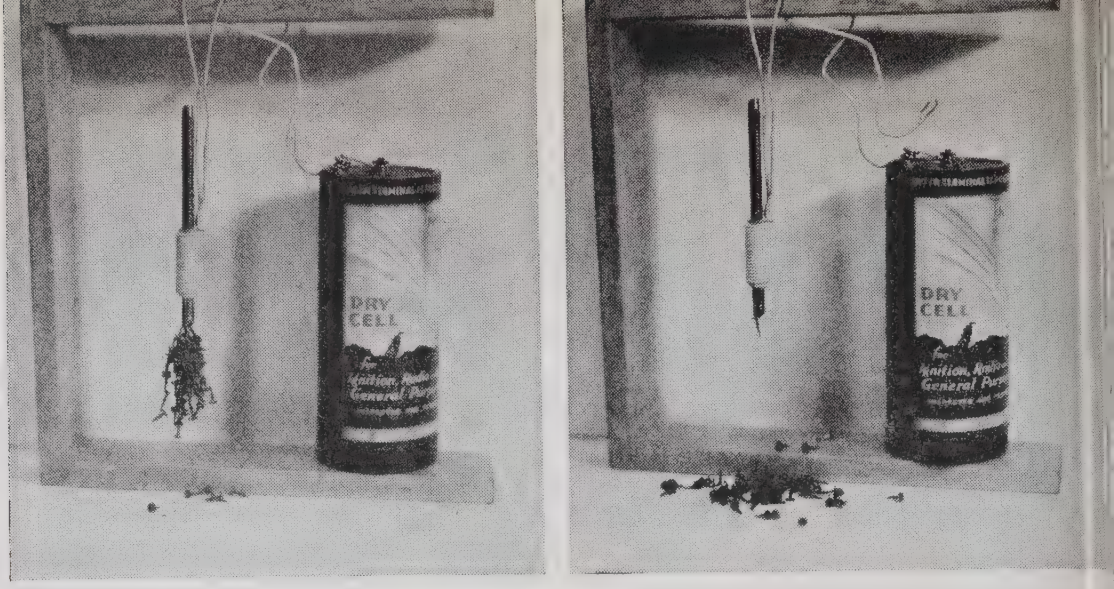


FIG. 172. Apparatus for Experiment 33a

HOW CAN YOU MAKE MAGNETS WHOSE FORCE YOU CAN CONTROL? One of the interesting sights in a steel mill is the loading of a car with scrap iron. Years ago the scrap iron had to be loaded by hand. Now a magnet is used for this purpose. This magnet travels on a beam. It is lowered into a pile of iron; and when it is raised, hundreds of pounds of iron are sticking to it. It next travels on the beam to a point over a car. Then suddenly the iron drops into the car. This kind of magnet is called an *electromagnet*. How do you suppose it works?

EXPERIMENT 33. *How Can You Make an Electromagnet?* (*a*) Dip a large nail into a box of carpet tacks. Does the nail act like a magnet? Now wind some cotton-covered or enamel-covered wire around the nail about twenty-five times. Connect the ends of the wire to a dry-cell and dip the nail into the tacks. Does it act like a magnet? Disconnect one end of the wire from the dry cell. What happens?

b) Wind the wire around the nail twenty-five more times. Again connect both ends of the wire to the dry cell. See how many tacks it will now pick up. Now connect two dry-cells and try it again. How may an electromagnet be made stronger?

Now you can see how the car in the steel mill is loaded. The center of the big magnet is made of soft iron. This

part is called the *core*. A large coil of wire surrounds the core. When the magnet touches the iron, a strong current of electricity is sent through the coil of wire that surrounds the soft iron core. The current is kept passing through the coil until the magnet is over the car. Then the current is turned off. Because the magnet is made of soft iron, it is only a temporary magnet. When the current is turned off, the magnet loses its force, and the scrap iron drops into the car.

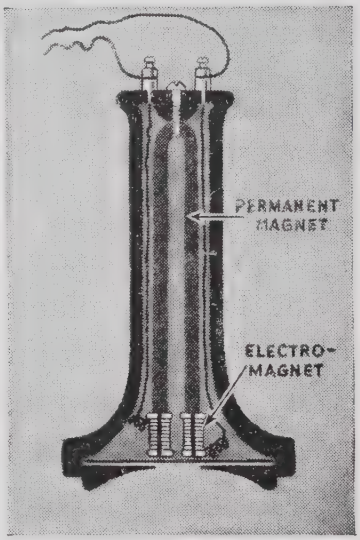


FIG. 173. A telephone receiver uses both a permanent magnet of steel and a temporary magnet, or electromagnet, of soft iron.

Electromagnets can be made to pick up very large loads. You saw in Experiment 33 that an electromagnet can be made stronger in two ways: (1) by putting more turns of wire around the iron core, and (2) by sending more electricity through the wire. When a very strong magnet is needed, many turns of wire are used, and a strong current of electricity is sent through them.

You use electromagnets every day. Every time you use a telephone or ring a door-bell, you are using an electromagnet. If you will take the cover off a bell, you can see one of these magnets. Unscrew the end of a telephone receiver which you put to your ear. Lift out the round plate, and look beneath. You will see another electromagnet. All electric motors contain electromagnets. Later on in your study of science you will learn how the electromagnets in bells, telephones, and motors work.

Self-Testing Exercises

1. How is an electromagnet made?
2. How can an electromagnet be made stronger? Give two ways of doing this.
3. Why are soft iron cores instead of steel cores used in an electromagnet?
4. Is an electromagnet a temporary or a permanent magnet?

Problems to Solve

1. What advantages does an electromagnet have over a permanent magnet?
2. What disadvantages do electromagnets have?
3. In some places trucks with huge electromagnets swinging close to the ground are driven over the automobile roads. Why do you suppose this is done?
4. What would happen if you made an electromagnet and used a bar of steel for a core?
5. A magician had a "magic wheel." People from the crowd were allowed to call out numbers, and without touching the wheel he would make it stop at any number they called. How could such a wheel be made?

Problem 3:
WHY DO MAGNETIC COMPASSES TELL DIRECTION?

On page 230 you read how a floating magnet could help to tell directions. Long ago you heard how Columbus used a *compass* to find his way across the ocean to America. You have probably played with small compasses such as Boy Scouts carry to find their way in the woods. You may even have seen the large ones used by surveyors and sailors. All these compasses are only magnets fixed so that they can swing around in a circle.

Do you know how to use a compass to tell directions? This is how you do it: Put the compass on something

level and see that there is no iron or steel near it. Let the needle stop swinging. Turn the case of the compass around until the N on the case is at the tip of the needle that points north. This end of the needle is usually shaped like an arrow or marked in some other way. East and south and west will then be shown by marks on the case, or *compass card*, of the compass.

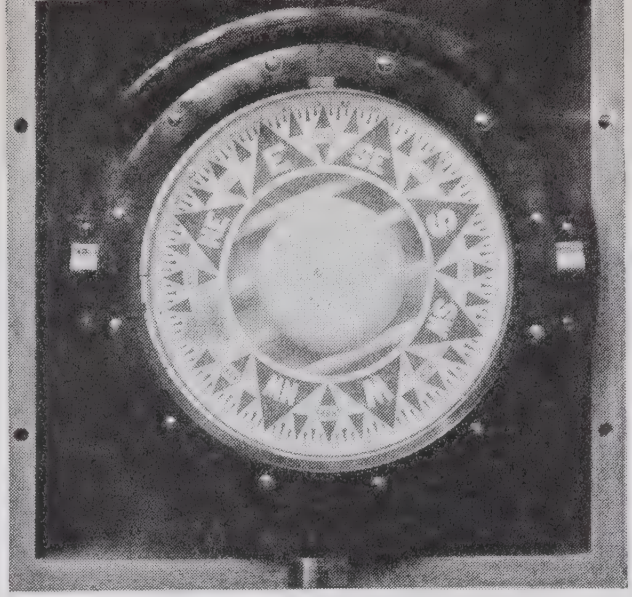


FIG. 174. In a ship's compass the *compass card* with directions on it is fastened to a magnet underneath. When the magnet turns, the card turns.

WHY DOES A MAGNET POINT NORTH AND SOUTH WHEN IT IS FREE TO TURN? We can learn the answer to this question by doing three experiments and some reading and thinking. You can make a compass out of any straight magnet or piece of magnetized clock spring.

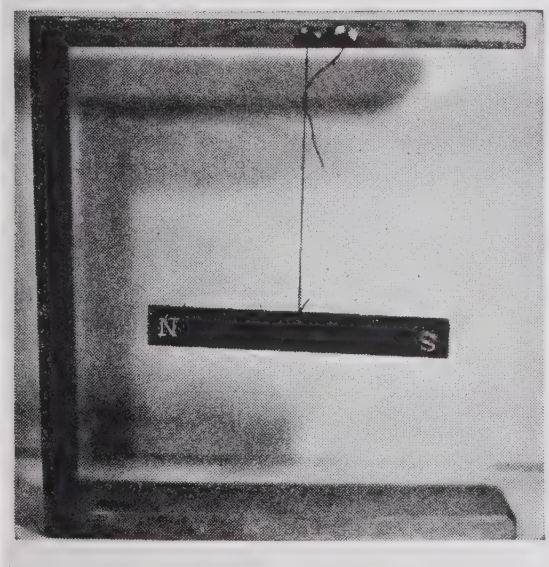


FIG. 175. Experiment 34

EXPERIMENT 34. *What Happens to a Magnet When It Is Hung on a Thread or String?* (*a*) Tie a long thread around the middle of a bar magnet and hang it up so that it will swing freely, as shown in Figure 175. Let the magnet come to rest. (NOTE: *Do not have any other magnet, or piece of iron or steel, near the magnet.*) In what directions is the magnet pointing? With a

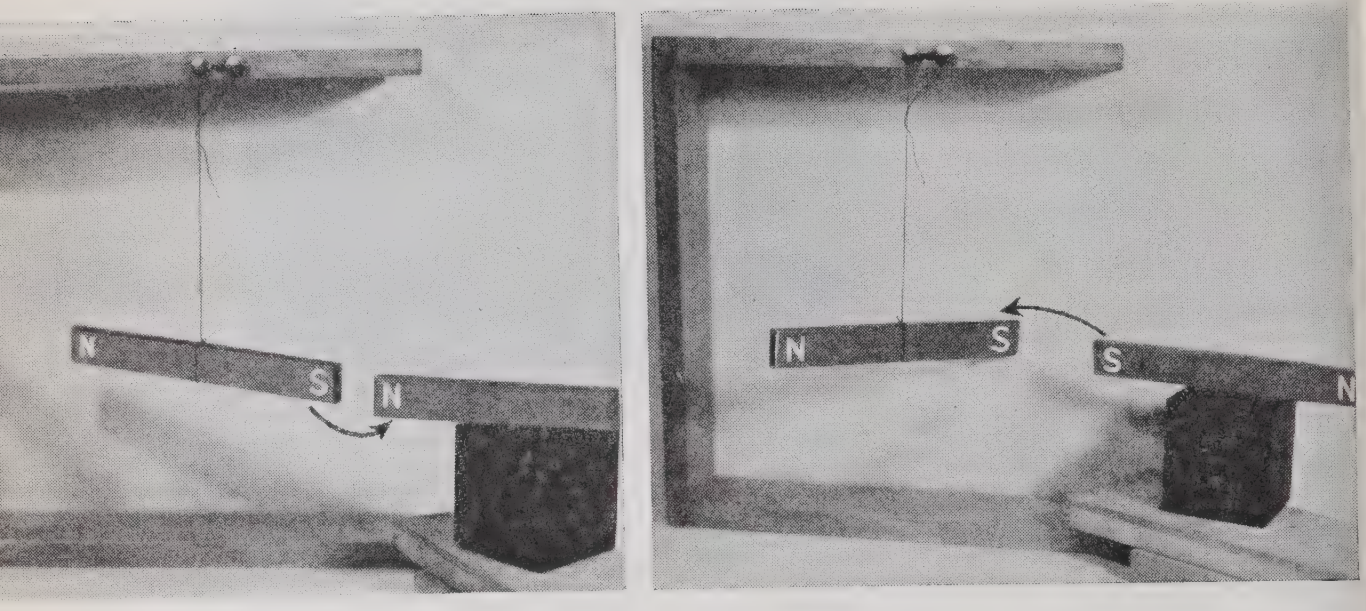


FIG. 176. Apparatus for Experiment 35

piece of crayon mark the end that points north N and the end that points south S.

b) Repeat the experiment, using another magnet. Mark the ends as you did before. Does this magnet point in the same directions as the other one did?

Now you have two magnets. On each magnet the pole that points north is marked N. This pole of a magnet is called the *north-seeking pole*, or the north pole or N-pole, for short. The pole that points south is called the *south-seeking pole*, or the south pole or S-pole.

A strange thing is discovered when we experiment with two magnets whose north-seeking and south-seeking poles are marked as we have marked ours. Let us see what this strange thing is.

EXPERIMENT 35. *How Do the Poles of a Magnet Act Toward Each Other?* (*a*) Suspend a bar magnet as shown in Figure 175. Let it come to rest. Hold the north pole of another magnet near the north pole of the suspended magnet. What happens?

b) Let the suspended magnet come to rest again. Bring the

south pole of the other magnet near the north pole of the suspended magnet. What happens this time?

c) Test the south pole of the suspended magnet with both poles of the other magnet. Are the results the same as when the north pole of the suspended magnet was tested?

From this experiment you can see that the north-seeking poles of two magnets push each other apart. We say that they *repel* each other. Two south-seeking poles also repel each other. However, when we bring a north-seeking pole near a south-seeking pole, they attract each other. Many experiments have shown that the poles of magnets always act in this way.

When you have done one more experiment, you will understand why a compass points north and south.

Experiment 36. *How Does a Magnetized Needle Act When It Is Near a Magnet?* Strongly magnetize a large sewing needle. Tie a silk thread tightly about the middle of the needle so that it hangs horizontally. Have the thread about five inches long. Lift the needle by the thread. Hold it about two inches above the middle of a bar magnet. Move it over one pole and then over the other pole, and watch what the needle does. Move it all around the magnet. Tell how the needle acts as you move it. You may want to make a map showing which way the needle points all around the magnet.

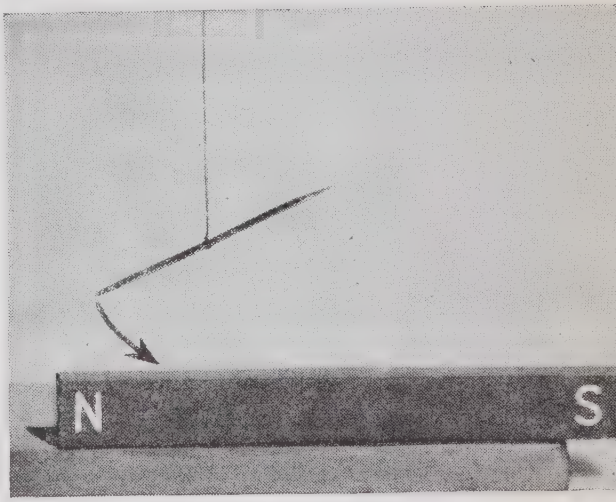


Fig. 177. Experiment 36

Does the needle seem to follow the lines of force you found with iron filings? If the magnet were under a piece of paper and you did not know where its poles were, could you locate them in this way?

Experiment 36 shows that a small magnet (the needle) gives the direction of the lines of force in the magnetic field around a large magnet. Over the N-pole of the magnet the S-pole of the needle pointed downward. Over the S-pole of the large magnet the other end of the needle pointed down. Between the two poles the needle pointed in the general direction of the N-pole or the S-pole, whichever was nearer.

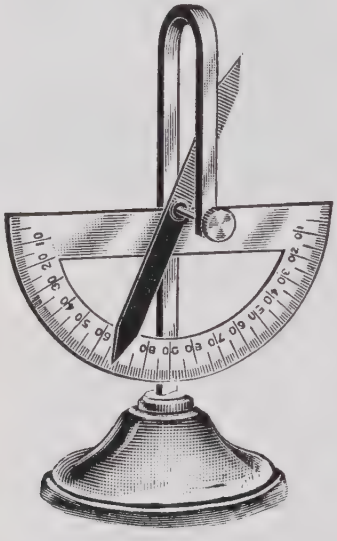


Fig. 178. A dipping needle

Scientists who go on exploring trips have a special kind of compass which they take with them. It is called a *dipping needle* (Figure 178). Like the needle you hung on a thread, the dipping needle can point up or down at any angle or stand parallel to the ground.

As explorers traveled about over the earth, they found a place in the far north where the N-pole of the dipping needle points straight down, just as yours did over the pole of your large magnet. In the far south they found a place where the S-pole of the dipping needle points straight down. In between these places the needle stands at all different angles. Near the equator the dipping needle stands level. In other words, when a dipping needle is carried about over the earth, it acts the same way your needle did when it was carried over and around the large magnet in Experiment 36.

There seems to be only one good explanation for the way a dipping needle acts. All experiments that have been tried seem to show that this explanation is right. The earth itself is a huge magnet! Its poles are in the

far north and the far south. The magnetic pole of the earth that is in the north attracts the north-seeking pole of a compass. The magnetic pole of the earth that is in the south attracts the south-seeking pole of a compass. Dipping needles and compasses show us the direction of the lines of force in the magnetic field of the earth. Now you can see why our compasses point north and south.

Self-Testing Exercises

1. What is a compass?

2. If you were lost in the woods on a cloudy day and had a compass, how would you use the compass in order to go straight west?

3. Peter Peregrinus, a Frenchman, studied magnets nearly 700 years ago. He said: (*a*) Magnetic poles that are alike repel each other. (*b*) Magnetic poles that are different attract each other. He called these statements the *laws of magnetic poles*. Were his laws right? How do you know?

4. How does a dipping needle show where the magnetic poles of the earth are?

5. Tell why a compass points north and south.

6. Why was it best to move all large pieces of iron or steel away from the magnets in Experiment 34?

Problems to Solve

1. Is the north-seeking pole of a magnet like the north magnetic pole of the earth? How do you know?

2. Would you expect a compass to point in the right direction if you were near a large deposit of iron ore? Tell why or why not.

3. If you were lost in the woods on a cloudy day, but had a piece of magnetized clock spring and a thread with you, how could you tell directions?

4. See how many reasons you can give for believing that the earth is really a large magnet.

5. Make a dipping needle. Get a long steel knitting needle and a darning needle that are not magnetized. Push the knitting needle through a cork in one direction and the darning needle through the same cork at right angles to the knitting needle. Balance the apparatus on two smooth jars or bottles, as shown in Figure 179, by pushing the knitting needle through the cork until it stands exactly level. Have the knitting needle pointing north and south.

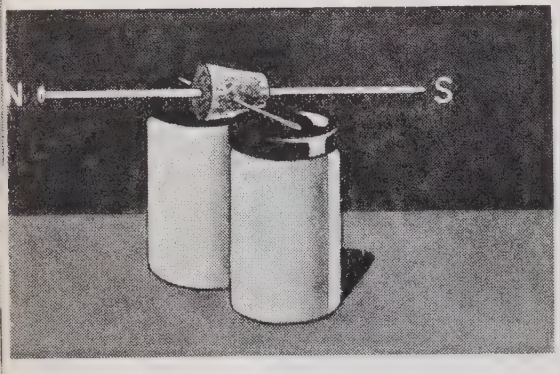


FIG. 179

Lift the needles and cork from the jars, being careful not to change the position of the needles in the cork. Magnetize the knitting needle strongly by stroking it many times with a strong magnet. Stroke both ends, but be careful to stroke both in the same direction with the same pole of the magnet. Put the apparatus back on the jars just as it was before. Is it still balanced? Why does it act as it does? Compare it with the dipping needle (Figure 178).

6. When a compass was placed on a certain table, the compass needle pointed to the east instead of to the north. The table was turned around, and the needle then pointed to the west. Explain.

7. If a piece of steel were hanging by the middle, as in Figure 175, how could you find whether it was a magnet?

WHY DO MAGNETIC COMPASSES NOT ALWAYS POINT TRUE NORTH? If you are lost in Maine and go north according to a compass, you will really travel a little northwest instead of straight north. If you are lost in Oregon, you will travel northeast instead of true, or exact, north. Now what is the explanation for this?

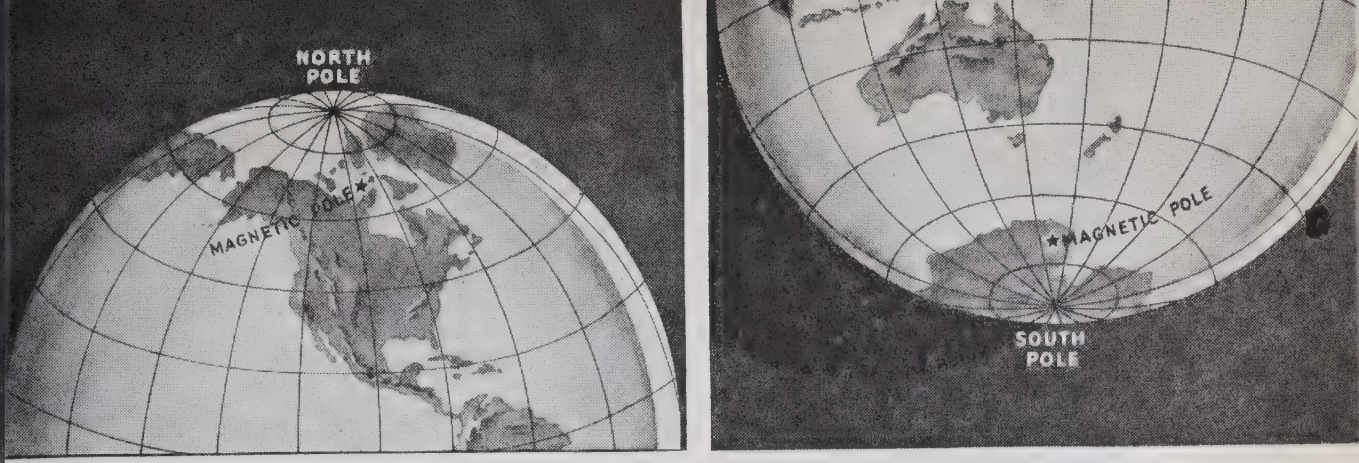


FIG. 180. The geographic and magnetic north and south poles

Why doesn't the compass needle point to the true north, no matter where you are on the earth?

By the use of the dipping needle, explorers located the north magnetic pole. They discovered that it is not at the real north pole of the earth. It is at a point near Hudson Bay, about 1300 miles from the north geographic pole. This place is shown in Figure 180. The compass needle is attracted by the *magnetic poles* of the earth, not by the *geographic poles*. You can see, then, that it will not point true north, because the magnetic pole is a long way from the geographic north pole.

The map on page 254 shows that at all points on the line marked "No Variation" the compass needle will point due north. This line is also called the "zero-degree" line. The other lines show how many degrees away from true north the compass needle will turn at places on those lines. East of the zero-degree line the compass points west of north. West of the zero-degree line the compass points east of north. To use a compass with great accuracy, you must know how much to change the compass reading for the place where you are. Navigators have charts that tell them how much to change the reading of the compass for the place where they are.

Strangely enough, the magnetic poles of the earth slowly change their positions. The constant moving of the

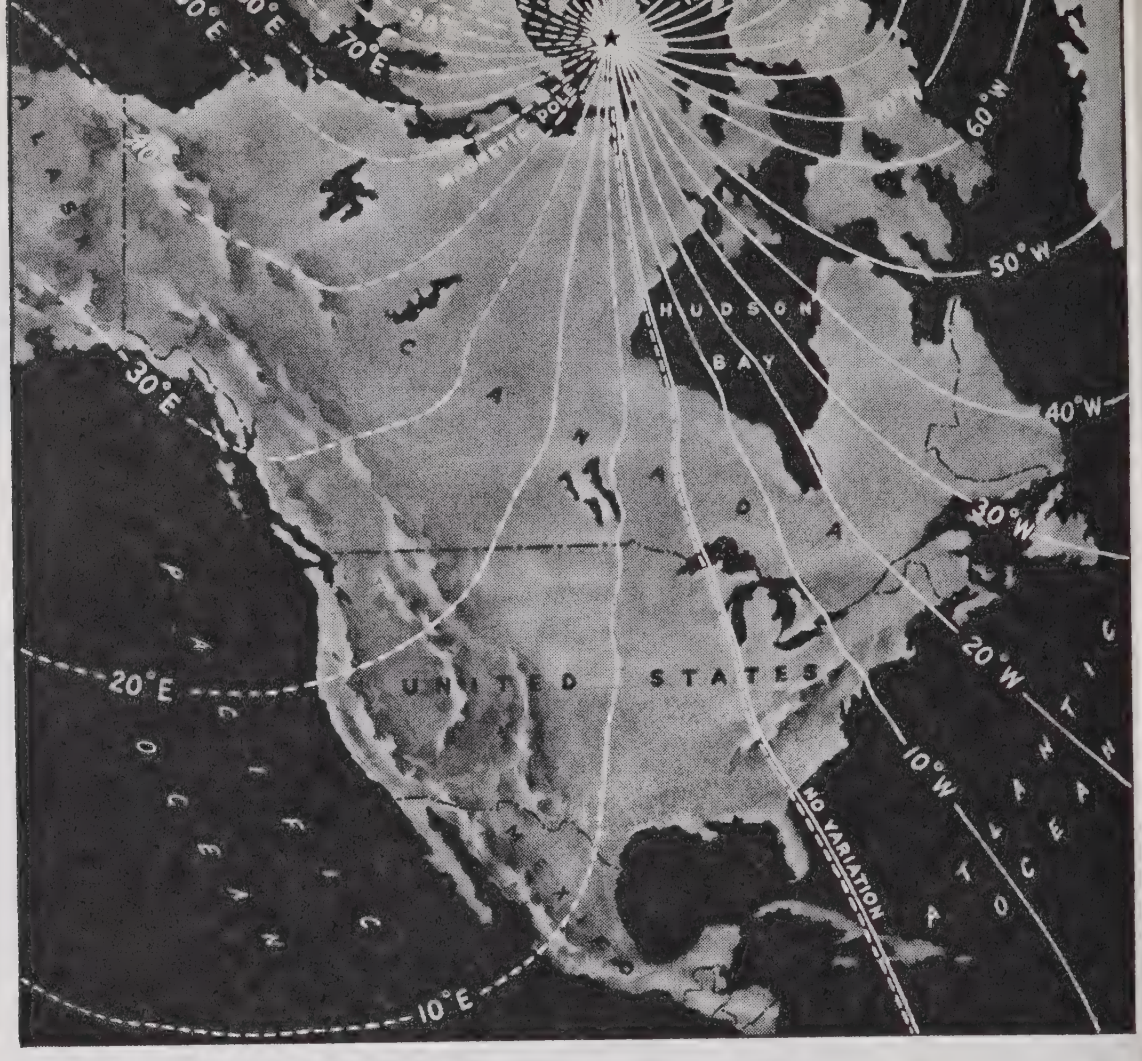


Fig. 181. The difference between the true north and the magnetic north is called *magnetic declination.* Only on the line marked "No Variation" does the compass point true north.

magnetic poles makes it necessary for governments to make new magnetic maps of the earth from time to time.

Self-Testing Exercises

1. Why doesn't the compass point to the true north no matter where you are?

2. How would a dipping needle act as an explorer passed over the south magnetic pole? Explain.

3. Find where you live on the map in Figure 181. Does a compass point north, or east of north, or west of north where you live? About how much?

4. If a compass always pointed true north, no matter where it was located, what would this tell you about the location of the north magnetic pole and the north geographic pole?

Problems to Solve

1. If you should look up the locations of the magnetic poles of the earth in several books published in different years, you would find that no two of them gave the same locations for the magnetic poles. Would this mean that the books were wrong? Explain.

2. Do you think the captain of a ship should pay any attention to the number of degrees his compass varies from true north? Why?

3. Compasses are never enclosed in iron boxes. Explain the reason for this.

4. Magnetize about a dozen large needles by wrapping wire around a cardboard tube and connect the ends of the wire to a dry cell as you did in Experiment 31. Place the points of the needles all in one direction as you put them inside the cardboard tube.

After the needles are magnetized, lay them on a heavy sheet of paper. Put the north pole of a strong bar magnet under the paper. Tap the paper lightly. Why do the needles take the positions they do? Now change ends with the bar magnet and tap the paper. Explain what happens.

5. Make yourself a compass by using a needle or a pin stuck in a thin board and a piece of the spring of a worn-out alarm clock. To suspend the piece of spring on the point of the needle, make a dent in the center of the spring with a hammer and nail. Then bend the ends of the spring downward about one half inch (Figure 182). Magnetize the steel as strongly as you can.

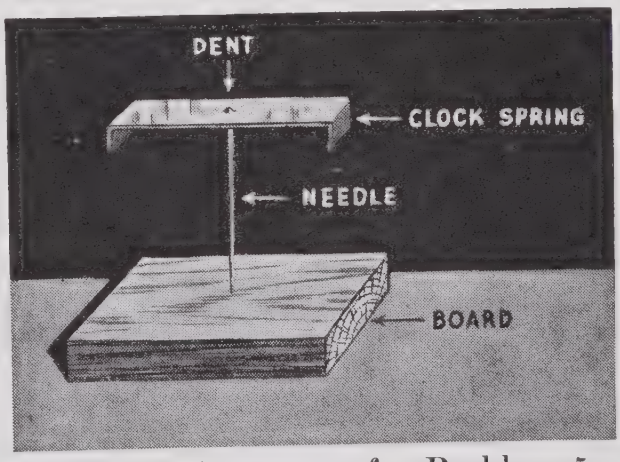


FIG. 182. Apparatus for Problem 5

PROBLEM 4 (Optional): HOW IS MAGNETISM EXPLAINED?

An ordinary piece of steel, as you know, is not a magnet. It becomes a magnet when it is rubbed on a magnet or when a current of electricity is passed through a wire wound around it. Some change must take place inside of the bar when it is magnetized. Nobody knows exactly what happens, but scientists have invented a theory that seems to explain the facts that we know about magnetism.

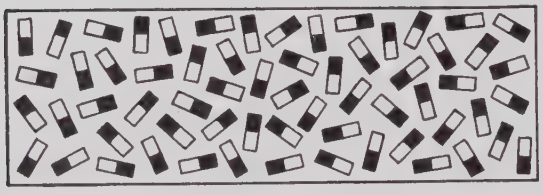


Fig. 183. Molecules in an unmagnetized steel bar

Let us see what the theory of magnetism is. The best explanation that scientists can give is this: (1) Every molecule of a magnetic substance is a tiny magnet. (2) Each molecule has a north and south pole. Now it would seem that if a piece of steel is made of molecules, each of which is a magnet, the steel would always be magnetized. But we know that this is not true. We can explain why a piece of steel is unmagnetized. When the steel is made, the molecular magnets arrange themselves in a "hit or miss" fashion. North poles face south poles, and there are as many north poles as south poles at the ends of the steel.

This fits in with our facts because we know that unlike poles attract each other. You can see how this arrangement will be if you examine Figure 183. When the molecules are in this position, the steel is unmagnetized because the north and south poles of each molecule *neutralize* each other. What happens is like what takes place when two boys are pulling on the opposite ends of

a rope with equal force. If one boy was pulling alone, the rope would move. But since both are pulling with equal force, nothing happens. So, in an unmagnetized bar the poles of the tiny molecule magnets just balance each other.

When a bar is magnetized, the molecules are moved into a new arrangement. The lines of force that pass through the bar (from the magnet or electric current that is used to magnetize the bar) cause the molecules to swing so that their poles are pointing in the same direction (Figure 184). Now the poles no longer neutralize each other; so the bar becomes a magnet. This is the theory that scientists have worked out to explain what happens when iron or steel is magnetized.

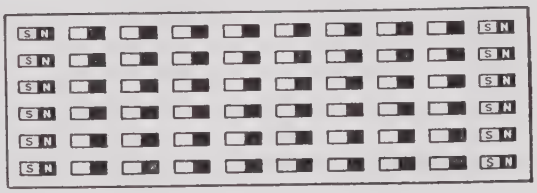


FIG. 184. Molecules in a magnetized steel bar

If our theory is a good one, it should explain other facts about magnetism. In Experiment 32 we found that when a magnet is pounded, it is weakened. Why does this happen? When a magnet is pounded, the molecules are shaken up. They are jarred out of their position in line. In this case some of the poles will neutralize each other, and the magnet will become weaker.

A magnet will also lose some of its magnetism if it is heated. (You might try to work out an experiment to prove that this is true.) As we know, the speed of the molecules is increased when the material is heated, and the material expands. The molecules can thus move around more easily, and they will change their position so that some of the poles will neutralize each other.

Curiously enough, if you break a magnet in two, you will find that opposite poles are found on each side of the break. If you draw a line through the middle of Figure 184, you will see why this is true. Here is another fact that is explained by our theory.

This is another example of how scientists invent and use theories. Through observation and experimentation they discover certain facts. They discover, for example, that a bar of steel when magnetized acts differently from an unmagnetized bar. They wonder why. Usually years, sometimes thousands of years, pass by before some brilliant scientist is able to explain the mystery. Finally someone gets an idea that seems to explain the known facts. The scientist accepts this as a possible explanation with which to work. Then he tests his idea in every possible way. He says to himself, "If this idea of mine is correct, then certain other things must be true also." He experiments to see if his explanation does work with these other things.

During his experiments he discovers new facts, and he tests his idea further to see if these facts also can be explained by his idea. Because of what he finds out from his experiments, he may need to change his original idea in some ways. Finally, after doing many experiments, he is sure he has a good explanation for all of the facts that he has observed. He calls his explanation a *theory*.

Self-Testing Exercises

1. Explain the difference between the positions of the molecules in an unmagnetized bar and in a magnetized bar, according to the theory of magnetism.

2. What experimental facts are there to support the theory of magnetism that you have just studied?

3. Suppose that you are a football coach and your team is not winning. You wonder why. How would you go about inventing and testing a theory to explain why your team is not winning?

Problems to Solve

1. Can you make a magnet that has only one pole? Explain your answer.

2. Read Problem 4 again. Why does the steel become a better magnet if it is pounded?

3. Why should you be careful not to drop a magnet?

4. Steel bars keep their magnetism better than soft iron bars. Suggest a possible explanation for this.

5. If an unmagnetized steel needle is held about one-half inch away from the pole of a strong magnet, the needle will become a temporary magnet. Work out an experiment to prove that this is true. Explain how the needle becomes magnetized.

LOOKING BACK AT UNIT SEVEN—SUMMARY EXERCISES

1. In this unit you have learned several new science principles that you can use to solve problems. Write them down as complete sentences, as you did for the earlier units.

2. Show that you know the meanings of these science words and phrases:

compass	*magnetic field*	*permanent magnet*
dipping needle	*magnetic substance*	*pole of a magnet*
electromagnet	*magnetism*	*south-seeking pole*
lodestone	*non-magnetic substance*	*temporary magnet*

ADDITIONAL EXERCISES

1. Plan an experiment, using a compass, that will tell which of two magnets is the stronger.

2. How could you increase the strength of an electromagnet? Test your idea.

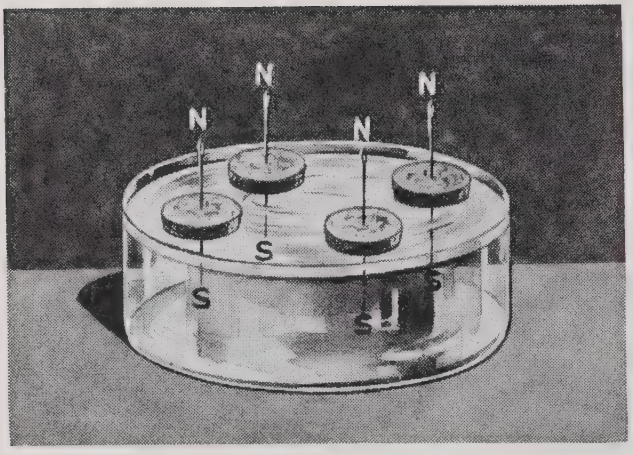


FIG. 185. Apparatus for Exercise 5

3. Two needles are suspended by fine threads. One is magnetized; the other is not. How can you discover which one is magnetized?

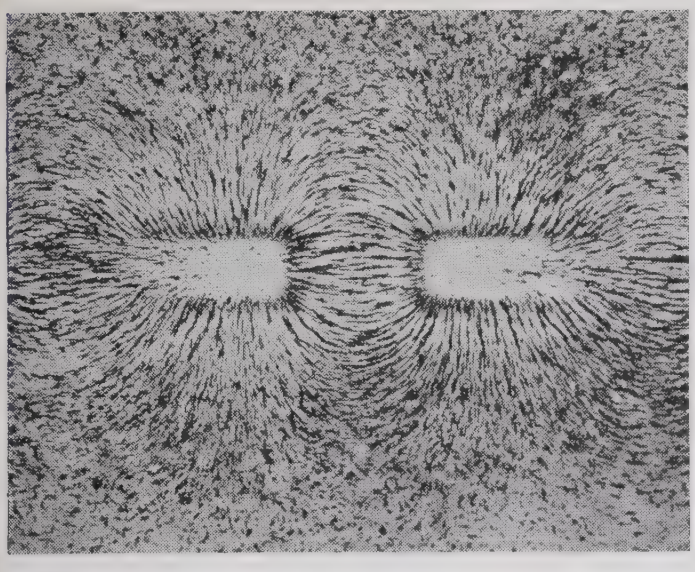
4. Suppose that you have a magnetized needle. How can you discover which end is the north-seeking pole?

5. (*a*) Cut four thin round slices from the end of a good-sized cork. Magnetize four needles just alike (as in Problem 1 or by stroking them with a strong magnet). Stick the point of each needle down through a slice of cork until the cork is at the middle of the needle. Put the corks close together in a shallow dish of water with eyes of all the needles up (Figure 185). Allow the water and the corks to become still. Do the corks come together? What do they do?

b) Now turn the corks over with all of the points of the needles up. Put the corks close together and allow them to become still. Do they act as they did before?

c) Turn the eye of one needle up, the point of another, the eye of a third, and the point of a fourth. Again move the corks close together and let them become still. What happens? Can you tell why?

6. (*a*) Place the north pole of one bar magnet about an inch from the south pole of another bar magnet. Lay a sheet of stiff paper over the magnets and sprinkle some iron filings upon the paper. Tap the paper as you sprinkle the filings. Does the pattern of filings that is formed show the map of the two magnetic fields? (See Figure 186.) Is there a pull between the fields of the north and south poles of these magnets? How can you tell?



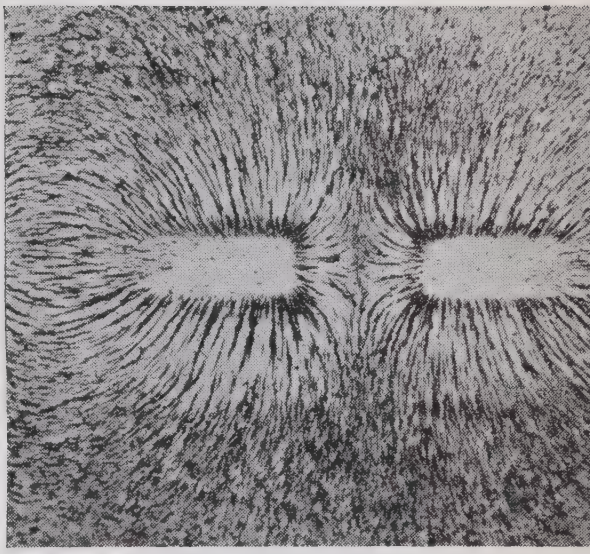


FIG. 186. At the left is the magnetic field of the north and south poles of bar magnets. At the right is the magnetic field of two north or two south poles.

b) Repeat the experiment, using a strong horseshoe magnet instead of the north and south poles of two bar magnets.

c) Repeat the experiment. This time place the north poles of the two bar magnets about an inch apart. Is there a pull between the north poles of the two magnets? How can you tell?

7. How can a magnet be made to float in the air? Drive two very long staples or U-shaped pieces of wire into a board about two inches apart. Slip a small cobalt-chrome or alnico magnet between the prongs of the staples. Slip another magnet like the first one between the prongs of the staples on top of the first magnet. Place like poles of the two magnets together. What happens to the magnet on top? Why?

8. Suppose you have two magnets of equal strength. Will the magnets pick up more tacks (*a*) when the magnets are held with like poles together, or (*b*) when the magnets are held with unlike poles together?

9. A hunter is using a compass to guide him. How might his gun interfere? What should he do with his gun when he

reads the compass? How can he be certain that the gun is not affecting the compass?

10. What devices have you seen that make use of an electromagnet?

11. Can you show that nickel is a magnetic material? Get a large brass safety-pin that is heavily nickel-plated. Hang the pin up by a fine thread about two feet long. Have the pin hang by one of its sides instead of by one of its ends so that it can swing around easily. Allow the pin to become perfectly still. Then bring a strong magnet near it. Explain why the pin behaves the way it does. (See page 232.)

Fig. 187. In Unit Two you learned that there are hundreds of thousands of kinds of living things. Study this picture. Would you believe that in a single drop of water you could find all the living things that you see in the picture? What you see are tiny plants and animals in one drop of water, magnified thousands of times. In this unit you will learn how these tiny creatures are like yourself and like all other living things.

UNIT EIGHT

UNIT 8

HOW ARE PLANTS AND ANIMALS ALIKE?

INTRODUCTORY EXERCISES

1. Turn back to Unit Three and to Unit Six for a few minutes to help you remember what you studied in those units. Then tell as many ways as you can in which a squirrel and a stone are alike.

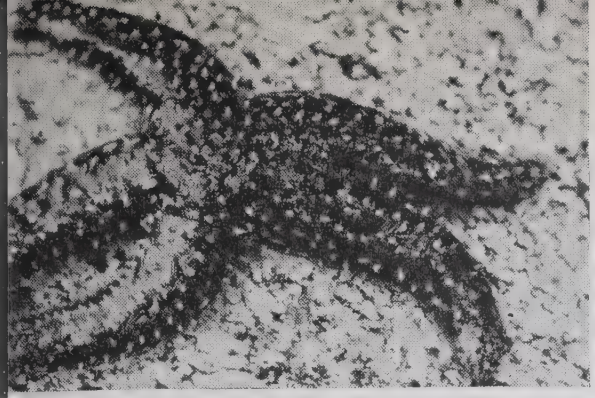
2. In what ways are a squirrel and a stone different?

3. Give all the ways you can think of in which an oak tree and a squirrel are different.

4. How are an oak tree and a squirrel alike?

5. Make a list of things that both plants and animals must do to keep alive.

6. What are the cells of living things? What is inside them? What do they do?



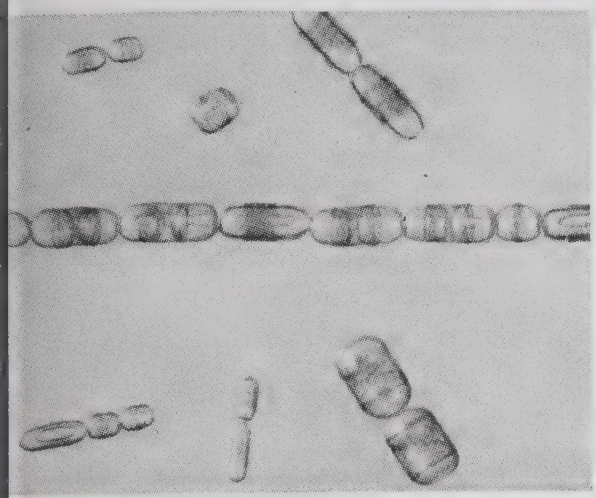


FIG. 188. Here are four different kinds of living things: (*top*) starfish, puff balls; (*bottom*) diatoms (seen through a microscope), sea-anemone. Which ones do you think are animals, and which ones are plants?

LOOKING AHEAD TO UNIT EIGHT

SO FAR in this book, most of your study of science has been about things that are not alive. But all around you is a world of living neighbors. We cannot get along without these plants and animals. What are they like? How are they made? Are chemical changes and heat, for example, important to them? Of course, things that are alive are made of matter, and they are affected by heat and cold. They use solutions, and they have many different chemical substances in them.

But living things are different from things that are not alive, and scientists study them just as carefully as they study non-living things. You are now going to think about some of the living things of the world. In other words, you are going to study *biology* (see page 64).

FIG. 189. When slime molds take the form of plants, they are in many different shapes. One kind looks like a soft brown fringe, as you see at the left above. Another kind looks like bunches of tiny clubs.

In Unit Two you learned that there are a great many different kinds of living things. You learned that most living things are either plants or animals. You may think that you can always tell plants from animals as easily as you can tell an oak tree from a squirrel. For one thing, it may seem to you that animals move around easily from place to place, while plants stay in the same places all their lives. But biologists know some strange things about plants and animals.

Suppose that you were to go into the woods on a day when the weather is moist and warm. You might find a clear, jelly-like mass sticking to the side of a fallen tree or to a dead leaf. If you marked its position with a pin and came back several hours later, you would probably find that it had crept up the side of the tree like an animal. If you came back several days later when the weather was dry, you would be surprised. The jelly-like substance you thought was an animal would be dried up. In its place you would find a flattened mass of material with many feather-like things that looked like plants. This

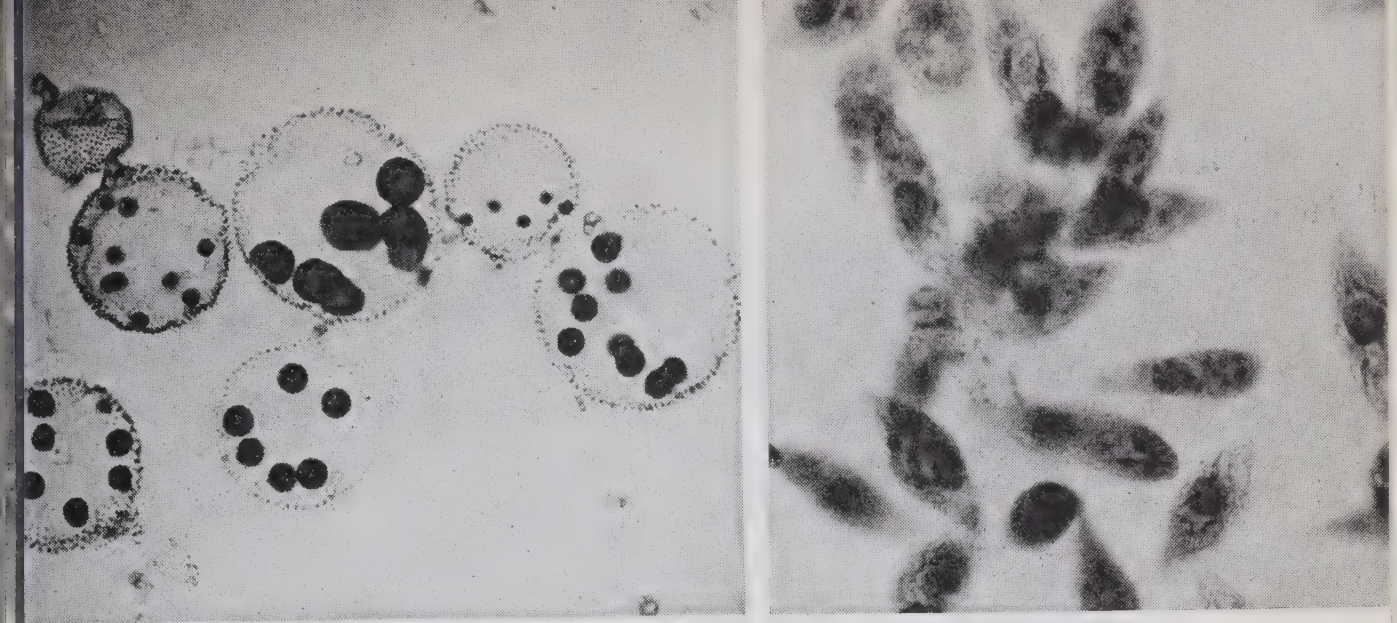


FIG. 190. These living things look like plants and act like animals. On the left is Volvox. Each Volvox is a hollow sphere made of many tiny living things. These are held together by a jellylike material, and the whole group acts as one living thing. On the right is Euglena.

kind of living thing is known as a *slime mold.* It is like an animal during the early part of its life, and like a plant during the latter part. Even the biologists are puzzled as to whether slime molds are animals or plants. Most biologists think they are plants.

Have you ever seen a pond of water that has turned green? Quite often when we put some of this green water under the microscope, we find that its color is caused by millions of tiny things like those at the right in Figure 190. They are alive, for they are rolling slowly through the water or swimming along in a jerky way. Are they plants or animals? Biologists have a hard time deciding. The important thing is that they are alive.

What does "being alive" mean? Perhaps if we can find out how the oak tree is like the squirrel that climbs the tree to get an acorn, we shall know something about what it means to be alive. Certainly we shall learn the ways in which the tree and the squirrel are different from soil, water, and air, which we know are not alive.

FIG. 191. Animals are affected by various kinds of *stimuli*. This baby rabbit is smelling the odor of clover, one of its favorite foods. We say that the odor is a *stimulus*. It makes the rabbit do something. He moves toward the clover and may eat it.

Problem 1:

HOW ARE PLANTS AND ANIMALS ALIKE IN WHAT THEY DO?

WHAT CAN ALL ANIMALS DO? It is very important to know what living things do. Let us begin by thinking what animals do. Think of any kinds of animals you please—cats, dogs, flies, spiders, earthworms, fish, birds, butterflies, squirrels, people. What can they all do? Probably the first thing that comes to your mind is that they all can move about from one place to another by crawling, walking, swimming, or flying. Yet there are some animals, such as sponges and sea-anemones (Figure 188) that cannot move about. However, they can all move some parts of their bodies.

Here are six things that all animals can do: (1) move at least a part of their bodies; (2) take in food; (3) breathe in oxygen; (4) give out waste materials from their bodies;

(5) produce young animals; (6) grow when young until they are about the size of their parents.

Animals can do another very important kind of thing. They can act in the correct way when messages come to them from their surroundings. What kinds of messages do animals receive? A light message comes to their eyes from each thing they see. Odors tell them when enemies or friends or food substances are near. Sounds are also important messages. We can talk about these different kinds of messages more easily when we have a special word for them. Biologists call all these different kinds of messages *stimuli* (singular *stimulus*).

The way an animal acts when it receives a stimulus is called a *response*. Most animals respond to stimuli from their enemies by running away, hiding, or fighting. When they are hungry, they respond to the stimuli from food by going toward it and eating it. All animals respond to stimuli in some way. This is the seventh thing animals do.

Can non-living things do the important things animals do? If you will think carefully, you will discover that some non-living things can take in oxygen and give out wastes. Others can move in response to stimuli, and still others can grow. For instance, stoves, automobiles, and locomotives take in oxygen and give out wastes. An automobile, a toy train, or a gun responds to the stimulus of a push or pull on a lever. Yet you will agree that these things are not done in the same way by an automobile as by an animal.

Did you know that there are a few things that grow even though they are not alive. The little sharp-cornered pieces of sugar, salt, and other chemical substances are

called *crystals*. Crystals can grow. You can watch them grow when you do the next experiment.

EXPERIMENT 37. *How Do Crystals Grow?* Obtain crystals of alum, copper sulphate, or sodium hyposulphate ("hypo"). Select one of these substances, powder some of it, and dissolve it in half a glass of warm water by stirring. Add enough powdered crystals so that after vigorous stirring there are some crystals left undissolved at the bottom of the glass.

Allow the solution to settle for fifteen minutes, and then pour most of the clear liquid above the undissolved crystals into a clean glass. Suspend a crystal of the substance by a thread in the clear solution. Set the glass in a quiet place for a few days. Does the crystal grow? How?

A crystal gets larger by adding new layers of the same material on the outside of the crystal. This is quite different from what happens when a living thing grows. A squirrel eats acorns and changes them into bone and muscle and skin and fur. This change takes place inside the body of the squirrel. Thus living things grow from the inside. When living things grow, their food is changed to living material. This new living material is added to the body; thus the body of the living thing gets larger.

FIG. 192. The mother robin is feeding worms to the baby birds. Inside their bodies this food will be made into feathers, bone, muscles, and other parts of their bodies. In this way they will grow larger.

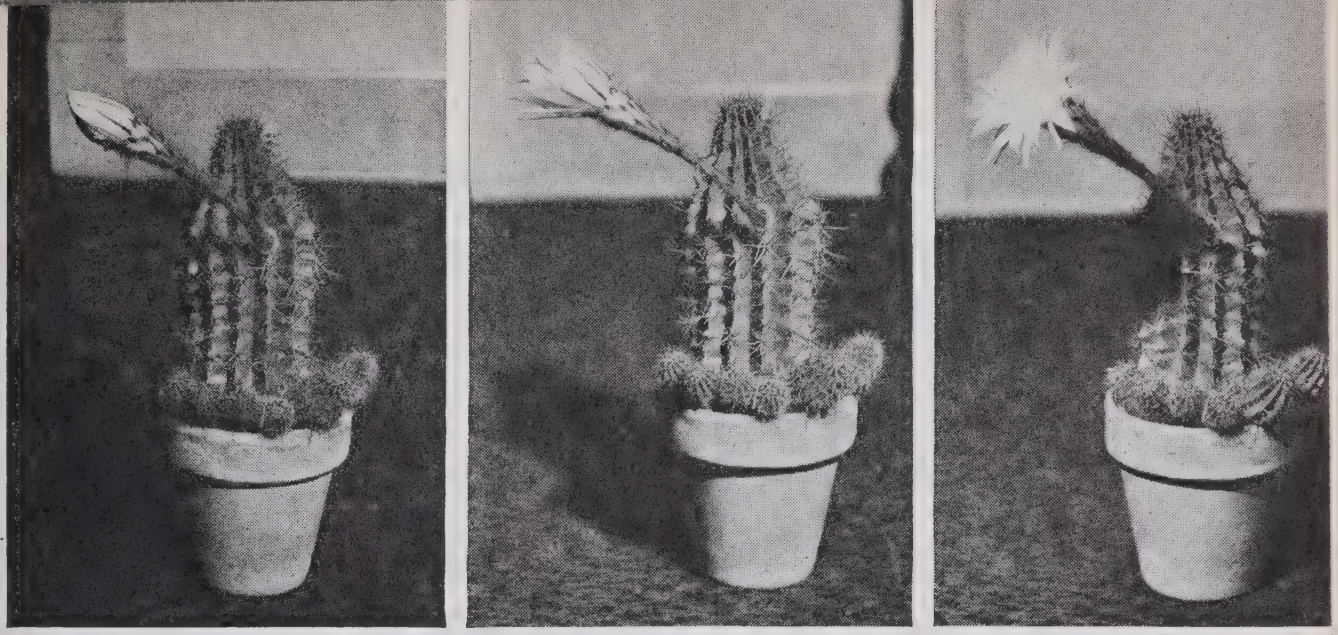


FIG. 193. This series of pictures shows the night-blooming cereus, a member of the cactus family, coming into flower. It took one hour and a half for the bud to open up into a full-blown flower.

You can see that *all* animals move some parts of their bodies, use food and oxygen, and give out wastes. They produce young, grow, and respond to stimuli. We may find a few non-living things that do one or another of these things, but no non-living thing can do all of them.

CAN PLANTS DO THE THINGS THAT ANIMALS DO? Can plants move? Certainly they cannot run around or hide and leap out to catch other things for food. Yet when we very carefully mark the place where the tip of a vine is and come back a few hours later, we often find that the tip has moved. Have you ever seen a motion-picture of a baby plant getting out of the seed or of a flower opening? If so, you have seen that plants do raise and lower their leaves and petals and wave their tips about in the air.

Do plants use food? You are not very much afraid that a plant might eat you, even in a tropical jungle. Yet plants must have some way to keep alive and to grow, just as animals must. Therefore plants must have food. You know that plants take in water and minerals through their roots. However, water and minerals are

FIG. 194. In many regions near factories, smoke or dust clogs up the leaves and stems of plants so that they do not get enough oxygen and are really "choked to death."

not true foods. In the next unit you will learn how plants get their food.

Do plants breathe? They surely do not have lungs or gills. They do not make any breathing movements that we can see. However, careful tests show that plants take in oxygen from the air through their leaves. They do not need as much oxygen as animals, because they are not as active. Still, they must have oxygen to keep alive. When fields of wheat and corn are covered by a flood for several days, the plants die or are badly injured because the water keeps the air away from their roots and leaves. Thus some plants can be drowned when they are covered by water, just as animals can be drowned.

Do plants give off wastes? You can do an experiment to help you answer this question.

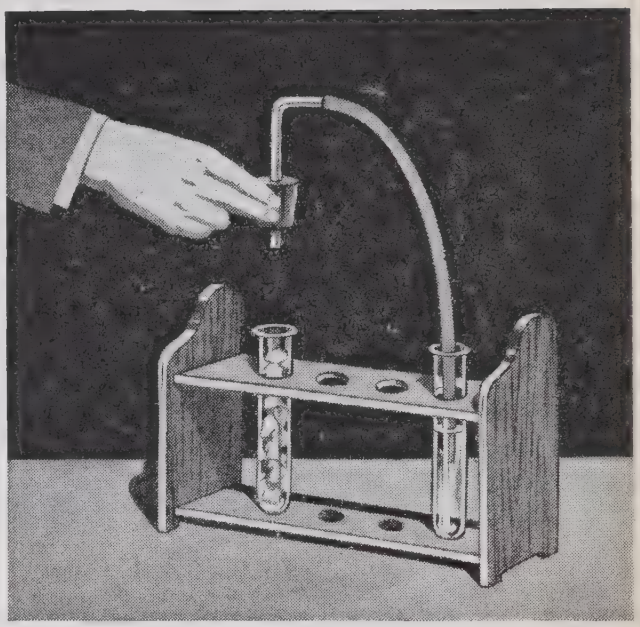


FIG. 195. Apparatus for Experiment 38a

EXPERIMENT 38. *Do Plants Give Out Carbon Dioxide As Animals Do?* (*a*) Arrange a test-tube, stopper, and tubing as shown in Figure 195. Put some small pieces of limestone into the test-tube. Fill a second test-tube half full of limewater that your teacher will have for you. Now pour some dilute sulphuric acid on the limestone. The limestone will give out bubbles of carbon dioxide (CO_2) when an acid is poured on it. Immediately put the stopper in that test-tube. Let the carbon-dioxide gas from the limestone and acid bubble through the limewater. The limewater should become milky white. (See page 193.)

b) Blow your breath slowly through a glass tube into some limewater. Does your breath have carbon dioxide in it?

c) Get two glass or stone jars large enough to cover a potted plant. The jars should have covers that fit rather closely. Into Jar A put a vigorous plant. Beside it, inside the jar, set a small glass of limewater. Put the cover on the jar. Into Jar B put a pot of moist soil the same size as the one with the growing plant. Put beside it a glass of limewater and cover it as you did Jar A.

Leave both jars for twenty-four hours. If the jars or covers are glass, the jars should be in a dark place. After twenty-four hours look at the limewater carefully. Which limewater has more white material in it? Which jar had the more carbon dioxide? Where did it come from?

In this experiment the jars were arranged so that they were different in only one way: One jar had a living plant in it that the other jar did not have. Almost always

FIG. 196. Maple trees have seeds with wide, flat wings. Some of them will fall to the ground; others will be scattered far and wide by wind. Many of these seeds will grow into new trees like the tree that produced them.

the limewater in the jar containing the plant has the more white material in it. The only reasonable explanation is that the plant gave out some carbon dioxide during the time it was in the jar. You also found carbon dioxide in your breath. Both plants and animals give out carbon dioxide as a waste material.

Of course you know that plants make other plants like themselves, just as animals produce young animals. Oak trees have acorns that can grow into more oak trees. And that yellow nuisance of the lawn, the dandelion, has hundreds of seeds that go floating through the air to start baby dandelions growing everywhere! Some plants, such as mosses and ferns, do not have seeds, but they produce young plants in one way or another.

And how plants can grow! They grow faster than animals, and some of them grow larger than any other living things. Trees are the largest plants, and the

great redwood trees of California have grown until they are the largest living things on earth, perhaps the largest that ever existed.

Do plants respond to stimuli? Have you ever seen a "sensitive" plant? This plant is unusual because its leaves fold together and droop whenever the plant is touched or shaken (Figure 197). Yet we do not need to have a sensitive plant to see that plants can respond to stimuli. Have you ever seen how the tip of a young sunflower plant turns toward the sun as the sun moves across the sky? Or how the flower of the four-o'clock closes after dark? Or how the leaves of clover fold at dusk? The plants are all responding to the stimulus of the sun's rays. Roots of plants respond to the stimulus of gravity by growing down into the soil, while the branches and leaves grow upward into the light and warmth of the sun. Plants do respond to many stimuli.

Now you can see that a plant and an animal are alike in many ways. They both grow; they both use food and oxygen; they both give out wastes; they both produce young that grow; they both can move either all of their

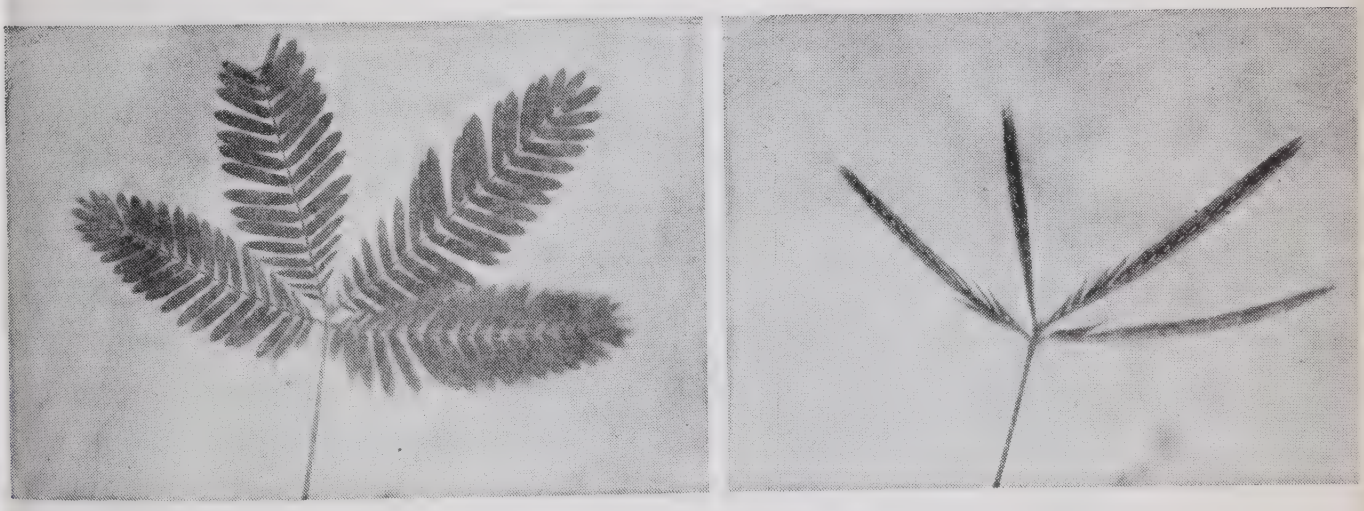


FIG. 197. The leaves of the sensitive plant, open and closed

bodies or parts of them; and they both respond to stimuli. Perhaps "being alive" really means doing these things.

Self-Testing Exercises

1. List the seven things that both plants and animals do. Then give an example of your own to show how each activity is carried on by animals and by plants, as shown below.

Activities of Living Things	Animal Examples	Plant Examples
1. Producing young	Turtles lay eggs from which young turtles hatch.	Young potato plants grow from potatoes that are put into the ground.
2. Etc.		

2. What is a stimulus? Give three examples.

3. How are non-living things different from living things in what they do?

Problems to Solve

1. Give as many ways as you can in which some one animal and a locomotive are alike. Why cannot a locomotive be called a living thing?

2. Plan and carry out some observations to see if you can notice movements of plants or parts of plants.

FIG. 198. The long, slender potato shoot has turned upward in response to the stimulus of light.

3. Plan an experiment to show that a plant responds to light, and another experiment to show that roots of plants grow down and stems grow up.

4. Read in books to find what kinds of animals cannot move from one place to another.

5. Write a paragraph telling how animals are different from plants.

FIG. 199. Is the opossum different from the flowers because it is made of different elements and compounds? You will find at least part of the answer to this question as you study Problem 2.

Problem 2:

WHAT CHEMICAL SUBSTANCES ARE LIVING THINGS MADE OF?

IN UNIT FIVE you learned that everything is made of chemical elements. You also learned what elements are: They are substances that cannot be separated into any other substances. There are ninety-two elements. All matter is made of these ninety-two elements. Plants and animals are made of matter. Even though they seem very different from each other and from non-living things, they must be made of elements. Are all ninety-two elements found in living things? If they are not all found in living things, which elements are living things made of?

You have also learned that compounds are substances made up of two, or more than two, elements. These compounds generally look different from the elements that are in them. What compounds are found in plants and animals? Are they special kinds of compounds

that can do things that other compounds cannot do? Are the compounds in plants different from those in animals?

WHAT ELEMENTS ARE FOUND IN PLANTS AND ANIMALS? Chemists have worked out many tests to find what elements are in the body of a plant or an animal. Chemists are also able to find out how much of each element there is. You already know the chemist's test for starch (page 161) and his test for carbon dioxide (page 193). When a chemist carries out such tests with any material, he is making a *chemical analysis* of the material to find what elements and compounds are in it.

Let us first see what chemists have learned about the elements in the human body. What elements would you expect to find most plentiful? How many elements would you expect to find? In Unit Five, page 155, you read about some of the substances found in the body of a man. You may be interested in reading that list again. Table 7 gives a more exact and complete list of the elements found in the human body. It also tells the number of pounds of each element that would probably be in the body of a person who weighs 100 pounds.

TABLE 7. COMPOSITION OF A 100-POUND PERSON

Element	Pounds	Element	Pounds
Oxygen (O)	65.0	Chlorine (Cl)	0.15
Carbon (C)	18.0	Magnesium (Mg)	0.05
Hydrogen (H)	10.0	Iron (Fe)	0.004
Nitrogen (N)	3.0	Copper (Cu)	Trace
Calcium (Ca)	2.0	Iodine (I)	Trace
Phosphorus (P)	1.0	Fluorine (F)	Trace
Potassium (K)	0.35	Manganese (Mn)	Trace
Sulphur (S)	0.25	Silicon (Si)	Trace
Sodium (Na)	0.15	Zinc (Zn)	Trace

You will notice that six elements make up almost the whole body. Most of the calcium and phosphorus is found in the bones. The rest of our bodies is made up chiefly of four elements: oxygen, carbon, hydrogen, and nitrogen. You should remember the names of these four elements; they are the elements that take part in almost all the chemical changes in living things.

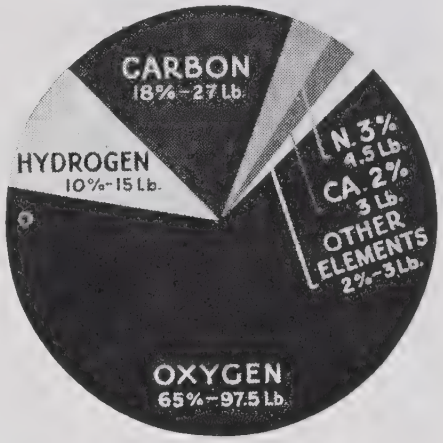


FIG. 200. This circle graph shows the approximate amounts of the various elements that make up a 150-pound person.

The last twelve elements in the list do not seem to be very important. All of them put together do not make much more than a pound. There is so little of six of them that the weight is not even given. Yet, if any one of these elements were missing, we probably could not go on living. The elements in the body of any common animal are very nearly the same as those in the body of a man. In a very different animal we would find more of some one element. Some sponges, for example, have much silicon in them.

Chemical analysis of plants shows the same elements that we find in animals. Every element found in animals is also found in plants. And the four leading elements in plants are the same four leading elements that are in our own bodies.

The element carbon makes one of the most important differences between living things and non-living things. Less than one five-hundredth part of the rock and soil on the outside of the earth is made of carbon. Yet about

Fig. 201. Most of what remains of this tree is a large mass of carbon.

eighteen per cent of living things is carbon. Thus, in proportion to their size, plants and animals have about one hundred times as much carbon as non-living things like rock and soil. In all plants and animals carbon is always the second element in amount. It makes up nearly one-fifth of the human body.

There is a simple test for carbon that we often make accidentally. If a substance turns black, or scorches, when it is heated, it almost surely has a large amount of carbon in it. If it gives off black smoke when it burns, it probably has much carbon in it. Think how many times you have proved that there is carbon in toast, potatoes, steak, and even in some of your best clothes! Your food and your clothes all came from plants and animals. The carbon in your food and clothes came, then, from plants and animals.

WHAT COMPOUNDS ARE IMPORTANT IN PLANTS AND ANIMALS? Suppose a chemist should get together the elements he would need if he could make a man weighing 150 pounds. These elements, under ordinary conditions, would fill a room sixteen feet wide, sixteen feet long, and sixteen feet high. How can all this raw material go into the body of one man? It can do so because hydrogen, oxygen, and some of the other elements in the human body are gases. These gases fill up a great deal of space when they are in the form of separate elements. But when the gaseous elements are changed

into the compounds found in the body, they become liquids or solids. Then they take up much less space.

One of the compounds you know most about makes up about two-thirds of the weight of plants and animals. That compound is water (H_2O). Water makes our blood liquid. It forms most of the perspiration, and it carries away important wastes from our bodies. It does many other useful things for us as well as for plants and other animals.

Our bodies, and those of other animals, contain small amounts of salt (NaCl). You have probably noticed that sweat and blood taste salty. If some of the material from your stomach has ever come up into your mouth, you have noticed that it tastes sour. That sour taste is the taste of hydrochloric acid (HCl). This compound of hydrogen and chlorine must be in our stomachs to help digest our food. The hard part of our bones is largely a compound called calcium phosphate ($Ca_3(PO_4)_2$). This compound contains calcium, phosphorus, and oxygen. Water, salt, hydrochloric acid, and calcium phosphate are rather common compounds; they are found in many places on, and in, the earth. In addition to these four compounds, there are a great many others that chemists have found in our bodies.

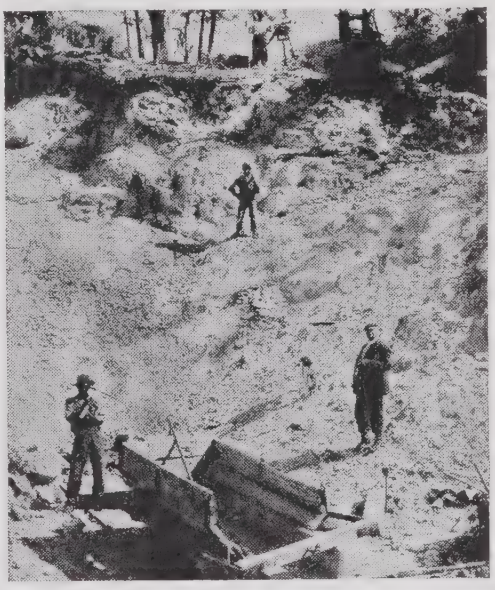


FIG. 202. In Florida there are large phosphate mines. Phosphate is a rock that is found just under the soil. It is dug out and ground up to be used as food-making material for plants.

But the compounds that make plants and animals different from non-living things are the compounds of carbon. That may seem strange to you, since you know that carbon is black. Very few animals are black, and even those that are black on the outside are not black

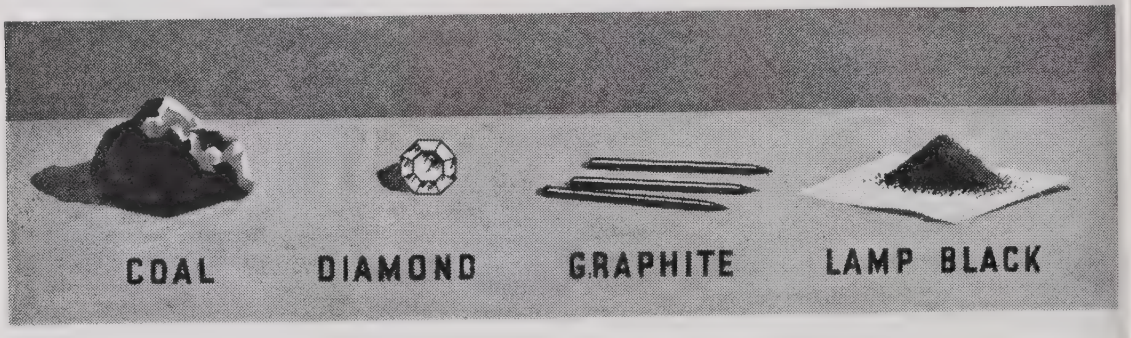


FIG. 203. Can you believe that all of these are different forms of one element, carbon? Carbon is found in many different forms and in many different compounds. Probably it is the various compounds of carbon that make plants different from animals and each kind of plant and animal different from all other kinds.

on the inside! We cannot eat the black carbon in charcoal and coke to keep alive. The carbon used by living things is all in the form of compounds. You know that these compounds of carbon act differently from the element carbon.

In some strange way, carbon is different from all other elements. Carbon is found in about ten times as many different compounds as all the other ninety-one elements. The simplest compound of carbon that you know is carbon dioxide (CO_2). You have already found that carbon dioxide comes out of the bodies of plants and animals. In the next unit you will learn how carbon dioxide is taken in again by plants. Thus it is not lost. It is really used to make all of the thousands of different kinds of carbon compounds found in plants and animals.

The presence of these many compounds of carbon also makes the differences between the parts of the different kinds of plants and animals. These carbon compounds produce the thousands of varied odors and tastes and colors of living things. Living things are all alike in that they make and use these compounds of carbon.

Self-Testing Exercises

1. Name the four elements found in largest amounts in the bodies of plants and animals.
2. What is the most peculiar element in living things? Give some reasons for saying that element is peculiar.
3. What compound makes up most of the weight of plants and animals? What elements are found in this compound?
4. What compound in the air is given off by living things and used again by living things? What elements are in this compound?
5. What parts of your body would be most harmed if you did not get enough calcium in your food?
6. How are plants and animals alike in the materials they are made of? Give as many different ways as you can.

Problems to Solve

1. How do the chemical substances in living things differ from those in non-living things? Give as many ways as you can.
2. Plan and carry out an experiment to find how much water there is in some plant or part of a plant.
3. Find in some book a table that tells the percentages of the elements in the outer part of the earth. Make a circle graph to show the most plentiful elements. Color each of the elements differently.
4. What substance is used by living things in the form of an element instead of in the form of a compound? Tell several things you know about this element.

Problem 3:

HOW ARE PLANTS LIKE ANIMALS IN THE WAY THEY ARE PUT TOGETHER?

WHAT DOES A MICROSCOPE SHOW IN THE PARTS OF PLANTS AND ANIMALS? One way in which common plants and animals are alike is that both are made up of parts, or *organs*. A bean plant has roots, a stem, leaves, flowers, and, later, a pod with seeds in it. These parts of the plant are called its organs. A dog has legs, eyes, ears, nose, body, and tail. Inside the body you know that there are lungs, a heart, a stomach, and other organs.

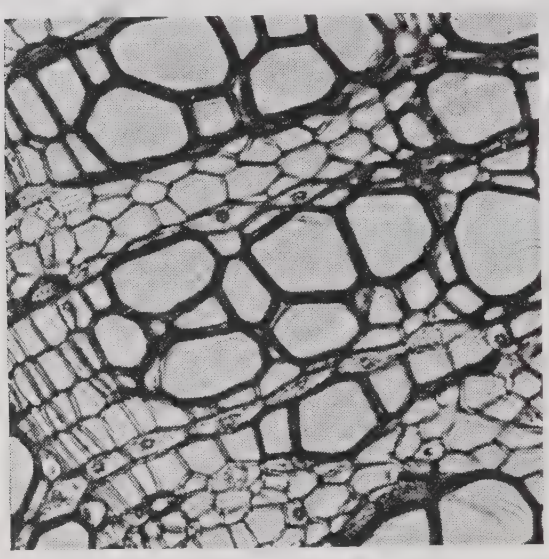


FIG. 204. A thin slice of wood as seen under a microscope. (General Biological Supply House)

When the microscope was invented, scientists began looking at the organs of living things. Then they found another way in which plants and animals are alike. Let us look at plants and animals as these early scientists did, to see what we can discover about the way they are made.

EXPERIMENT 39. *What Do Plants and Animals Look Like under the Microscope?* (*a*) Look at the cut edge of the following things with a good magnifier (simple microscope): cork, tomato, apple, a maple twig, and a celery stalk. Use a very sharp knife, like a safety-razor blade, to make the cuts. Very thin slices covered with water on a small strip of glass will show best.

b) Now look at the slices under a compound microscope (low power). You can see the objects more clearly if you lay a very thin piece of glass on top of them. Look also at

leaves of water plants and the tiny thread-like green plants that grow in water. Do the things you look at seem to be built in little sections? These little sections are called *cells*.

c) With the compound microscope look at thin slices of the parts of some animals. You will need to use specially prepared slices of material fastened on little strips of glass. These are called permanent microscope slides. You can probably borrow some from a biology room in your school. Look at the skin of a frog, thin slices of the brain or spinal cord of some animal, the lining of a stomach or large intestine, and the blood of a frog or bird. Do they have little sections, or cells, in them, too?

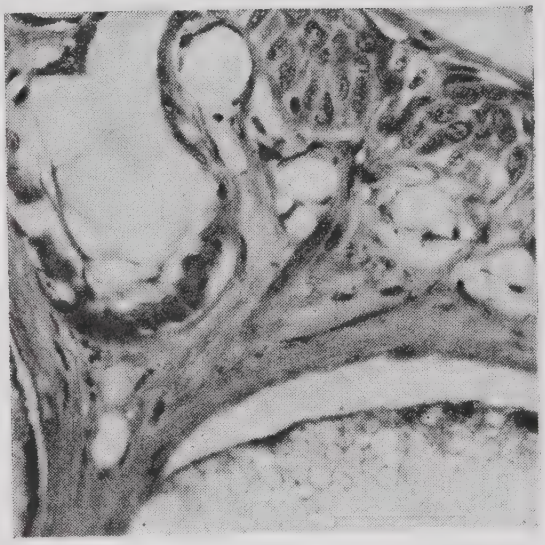


FIG. 205. A bit of the skin of a frog as seen under a microscope. (General Biological Supply House)

Perhaps your teacher will show you how to scrape a little of the lining from the inside of your mouth and put it on a glass slide to look at. When you have a blister or some skin peels from your body, put the skin in some water, then on a slide, and see if you can find cells in it.

Imagine the surprise of Robert Hooke, an English scientist, when (about 1665) he looked at a piece of cork under a microscope. Hooke saw that the cork was made of tiny compartments, or hollow spaces with walls around them. These little compartments looked like the cells in a prison or in a honeycomb; so Hooke said that the cork was made of *cells*. Inside all living cells is a liquid material. We now know that the liquid in living cells is more important than the walls of the cells.

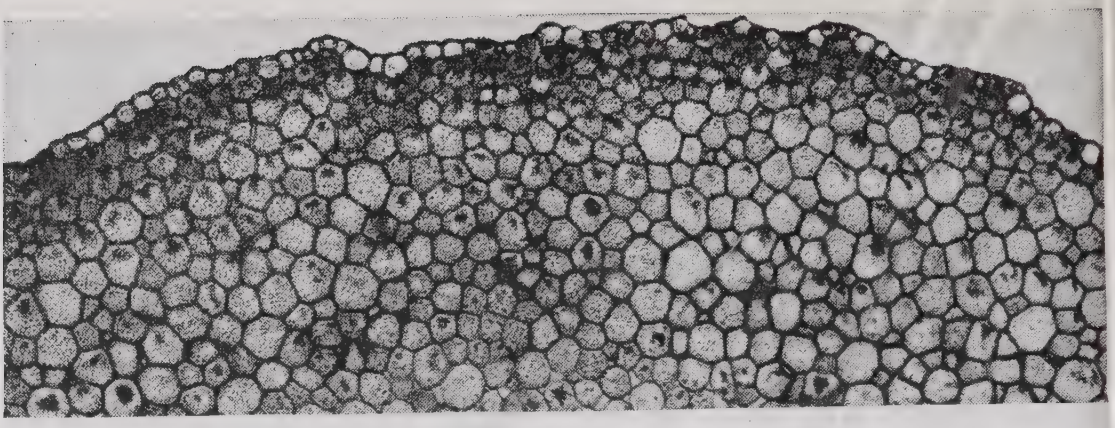


FIG. 206. The cells in a fern stem look like this when they are magnified hundreds of times.

As time went on, more and more scientists saw cells in more and more living things. They did not see them in things that had never been alive. About one hundred years ago two German scientists, Matthias Schleiden and Theodor Schwann, after very careful study, said they thought that all plants and all animals were made of cells. They also thought that everything that living things make and do is made and done by these cells. We now know that they were right.

The bodies of all living things are made of cells like those you saw with your magnifier and microscope. When you know how to look for them, you can often see them without a magnifier in *pith* (the central part of plant stems) and in fruits. Your body, a squirrel, an oak tree, or any living thing you care to mention, is made of cells. These cells make up the body much as bricks or stones make up the walls of a building.

But most cells are not dead like bricks and stones. They are alive and doing things. If your heart, your muscles, and your brain are made of cells, then the cells must be "beating," moving, and thinking. If the tiny

oak tree that grows from an acorn is made of cells, then cells must grow and multiply as the tree grows. That is what happens. The cells get larger, and the cells make new cells.

WHAT ARE CELLS MADE OF? If you have a compound microscope, you can see the most important parts of some cells.

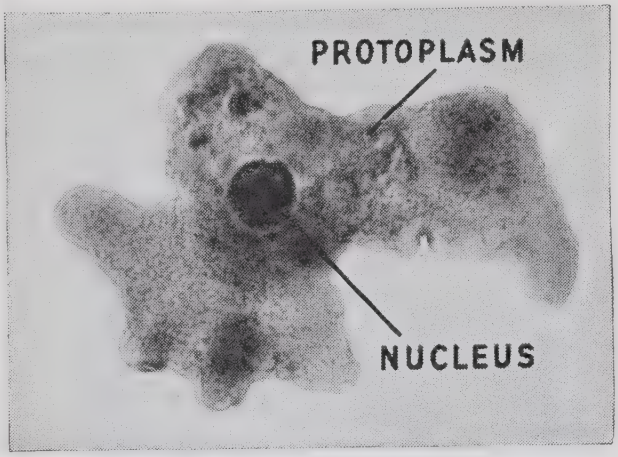


FIG. 207. The amoeba, a one-celled animal, has protoplasm and a nucleus. All other living cells have these same parts.

EXPERIMENT 40. *What Are the Parts of Cells?* (*a*) If possible, your teacher will show you an amoeba in a drop of water under a microscope. The amoeba is just one cell. Can you see the clear, grayish material of which the animal is made? This is the living part of the animal, and it is called *protoplasm*. Watch the animal to see what the protoplasm is doing. Look for a darker, biscuit-shaped piece of the protoplasm inside the animal. This is the *nucleus* (plural *nuclei*). Usually it is very hard to see in a living amoeba. What have you learned about cells by looking at the amoeba?

b) Cut a slice out of a small onion, and select a piece of one of the thick, juicy layers of the onion. With a pair of tweezers peel off a piece of the inner or outer skin of the layer. Spread the piece you get on a glass slide in some water. Put a piece of very thin glass (cover glass) on top of the water and onion skin. Look at the cells of the onion skin with the low power of the microscope. These cells have prominent walls between them. Make a drawing of a group of six or eight cells to show their shapes and how they fit together.

Look for a small, round, yellowish lump inside each cell. This is the nucleus of the cell. You should see a nucleus in each cell if the cells have not been torn to pieces. Look for the clear protoplasm around the nuclei or in little streaks near the cell walls or across the cells. You will need to look carefully to see it, and you may not see it at all. Show in your drawing the nuclei, and the protoplasm if you were able to see it.

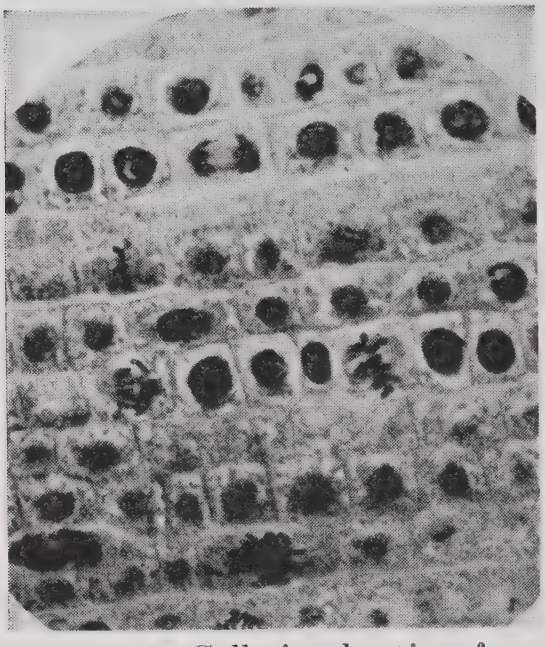


FIG. 208. Cells in the tip of an onion root under the microscope. The dark spots are nuclei.

All living cells have inside them a clear, syrup-like material that is somewhat like white of egg. We call this material *protoplasm.* Each cell has also a rounded, darker piece of protoplasm. This is the *nucleus.* Without its nucleus a cell cannot live long. Practically all living cells have these two kinds of protoplasm, the lighter protoplasm and the darker protoplasm that makes the nucleus. Many cells have a *cell wall* that the protoplasm has made around itself. In wood the cell walls are very thick and strong. These walls make wood so stiff that it can be used for buildings.

However, there are many cells, especially in animals, that make no cell walls around themselves. Even our bones have cells in them. Through chemical change, the bone cells have built the hard calcium phosphate around them to make our stiff, hard bones. You can understand this better if you imagine a building first

made of little blocks of jelly which later made hard, strong concrete around themselves. The little cells go on living in the bone. Then, when the bone is broken and needs repairing, or when it is growing larger, the cells are ready to do the work.

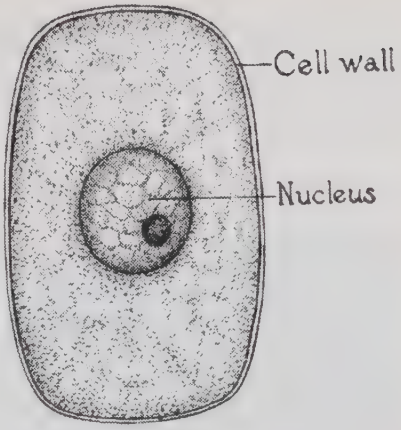


FIG. 209. One kind of cell commonly found in plants

Cells have many different shapes and sizes. A large amoeba is about 1/100 of an inch across. It is really quite a large cell. The smallest cells we know are *bacteria*. These bacteria are so small that they can hardly be seen with the best microscopes (Figure 210). But what would you think of a cell that weighs nearly one pound? The yolk, or yellow part, of an ostrich's egg is a single cell and weighs that much. Part of it is made up of food to help it grow into a young ostrich.

Some of the nerve cells in your body have long, slender branches that reach all the way from the lower part of your backbone to your big toe. Think how long the nerve cells of an elephant must be! But most cells of animals are very small. They are even smaller than the cells of plants.

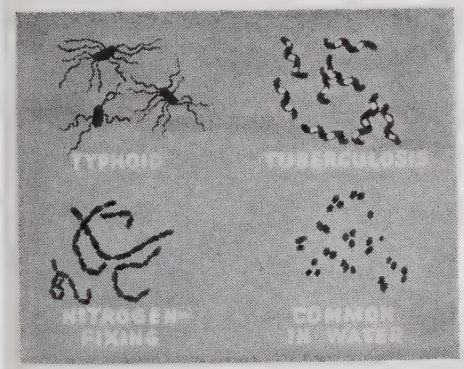


FIG. 210. One-celled plants, called bacteria, magnified 2000 times

Each large plant or animal has many different kinds of cells. Our own bodies have long, slender nerve cells to carry messages; muscle cells to help us move; rounded cells to hold stored fat; and flat, thin cells

to form a covering for the body. Some of these different kinds of cells are shown in Figure 211. Plant leaves have coverings of flat, thin cells, and they have long, slender cells, like tubes, to carry liquids through their stems and leaves. Some of these different kinds of plant cells may be seen on pages 284, 286, and 288. Thus you see that each different organ and part of an organ in plants and animals has its own kinds of cells.

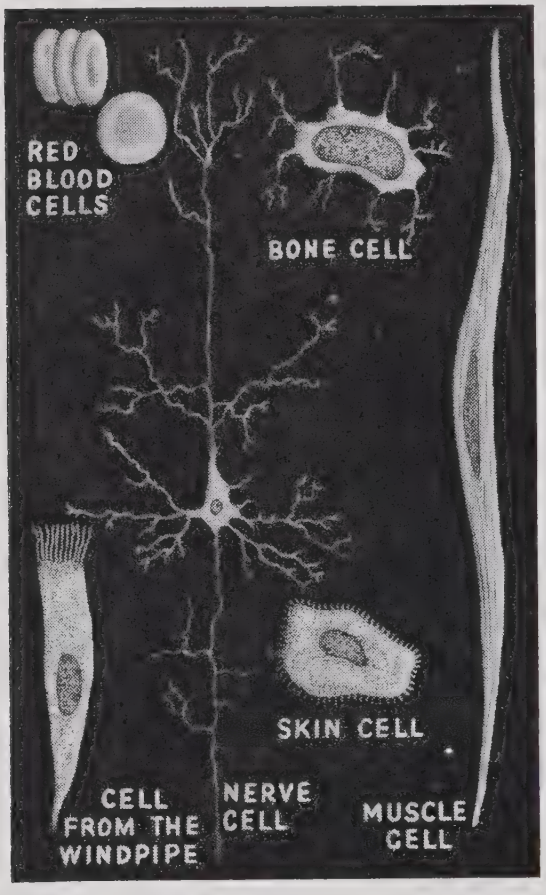


FIG. 211. There are many different kinds of cells in the human body.

You can also understand that each different kind of cell has its own work to do. Each kind of cell is made in its own way; it has its own peculiar shape and is fitted to do its own kind of work. Thus the body of a plant or of an animal is like a community of people. The cells all work together, each kind doing some special work for all the other kinds. If one kind is hurt or dies, the whole community of cells (plant or animal) is disturbed.

A community of one million billion (1,000,000,000,000,000) people, all working together, is hard to imagine. Yet each of us is a community of about that many cells! And most of the time they work together very well. Your brain has about two thousand billion cells in it. Your blood contains about fifteen thousand billion cells.

Plants are like animals, for they, too, have great numbers of different kinds of cells that work together. Each different kind does its own work.

WHAT DOES THE PROTOPLASM IN CELLS DO? A great scientist once said that a cell is just a bit of protoplasm with a nucleus in it. Of course, cells may have other parts, such as a wall, but the living, active part of the cell is the protoplasm. This protoplasm is a strange mixture of the compounds you learned a little about in Problem 2. No scientist has ever been able to put the right things together in the right way to make protoplasm. So far as we know, the only way we can get protoplasm is to have it made by other protoplasm.

In Problem 1 you learned that all living things do certain things. They all use food. The food must contain the elements and compounds needed by the protoplasm. All living things take in and use oxygen and give out waste materials. All grow by making more protoplasm out of food. All produce young. All respond to stimuli.

Now do you see what this simple-looking, syrupy material called protoplasm can do? It is the only living part of plants and animals. It is really doing all the things that you and plants and other animals do. Protoplasm takes in food. From that food it makes all the chemicals the body needs. From the food it also makes more protoplasm so that we can grow and repair the worn-out and injured parts of our bodies. Protoplasm takes in oxygen and uses it and gives out waste materials. Protoplasm causes cells or groups of cells to break loose from older plants and animals to grow into new plants and animals. Protoplasm sees and hears and tastes and smells and feels for us. Protoplasm responds

FIG. 212. "Pond scum" is made up of simple, thread-like plants that look like this under the microscope. They are called *algae*. (See Problem 6, on page 294.)

to all kinds of stimuli in many ways. All plants and animals are alike in what they do because they all are made of protoplasm. What wonderful stuff protoplasm must be! And yet you have not learned half of its wonders!

Self-Testing Exercises

1. Write a paragraph in which you tell what cells are.
2. What is protoplasm? What can protoplasm do?
3. What can cells do?
4. Tell some of the ways cells are different from each other.
5. How is the body of a plant or an animal like a community of people?
6. Problem 3 tells at least three new ways in which plants and animals are alike. What are these three ways?

Problems to Solve

1. What does an amoeba do? How do you know? Find out by reading how it carries on each of these activities.
2. Why do plants and animals need different kinds of cells?
3. What can protoplasm do that chemists cannot do in their laboratories?
4. What elements would you expect to be most plentiful in protoplasm when it is analyzed?
5. Suppose you went into a cave and found small, icicle-like things hanging from the roof of the cave. You returned to the cave a year later and found that the icicle-like things

were a little larger than when you first saw them. They seem to be alive because they are growing. Make a list of the things you could do to find out whether they are really alive. How would you know after you had tried your experiments?

LOOKING BACK AT UNIT EIGHT—SUMMARY EXERCISES

1. Use from one to one and a half pages of large notebook paper to write the answers to the following questions. Answer each question in one paragraph.

a) How are plants and animals alike in what they do?

b) How are plants and animals alike in the compounds and elements they contain?

c) How are plants and animals alike in the way they are put together?

2. Show in some way that you know what the following words mean:

protoplasm	*carbon dioxide*	*cell*	*oxygen*
carbon	*chemical analysis*	*nucleus*	*stimulus*

ADDITIONAL EXERCISES

1. A queer-looking plant, called a *fungus*, is growing on the side of a dead tree. Do you think it gets food to live? If so, where do you think it gets food?

2. Put an egg under a "sitting" hen or into an incubator kept at 103 degrees Fahrenheit. Put a bean between pieces of moist blotting-paper. Keep the paper moist. At the end of five days break the egg into a saucer of warm salt water and compare it with the bean. What has happened to both of them? How are the things that have happened to both of them alike?

3. Get a potted plant. Wrap the pot in waxed paper so that water cannot evaporate from the pot and soil. Fasten the paper around the stem of the plant, leaving only the

stem and leaves sticking out. Put a large glass jar over the plant and leave it for several hours. Be sure that the jar is clean and dry before you use it. What do you find on the inside of the glass? Where did this come from?

4. All living things respond to such stimuli as light, heat, chemicals, and water. Which make more different kinds of responses, plants or animals? Can you find out why?

5. Read in books about the kinds of plants that have no seeds—algae, fungi, mosses, ferns, etc. Then see how many of these kinds of plants you can find for yourself.

6. If you have a chance to use a microscope, see how many different kinds of tiny animals you can find or raise.

a) Collect a jar full of "pond scum." This is made up of thread-like plants, called *algae*, that grow in water. With scissors cut off a few of the threads and put them on a glass microscope slide with two or three drops of water. Use needles to spread out the material so that it is thinly scattered over the slide.

Look at the algae with the low power of the microscope. Usually many tiny animals will be seen moving along the plant threads searching for food. Look at similar material collected from different places. Do you find the same kinds of plants and animals?

b) Crowd some of the "pond scum" you have collected into a small jar and let it stand for a few days. Or stuff some dead leaves or grass into a small jar of pond water. From time to time put a few drops of the water on a slide with a medicine dropper and look at it under a microscope.

As the plant materials decay, many tiny animals usually grow in the water. Most of these are one-celled animals. Make drawings of the ones you find. Look in books to find their names. Try to find out how they do the things that all living things do. How do they act when they run into something?

FIG. 213. Each living thing, whether it be a tiny plant or an elephant, spends part of its time finding food and taking it into its body. Living things have countless different ways of getting food. Spiders build sticky webs, in which insects become caught, like the dragon-fly above. In this unit you will find out how different living things solve the problem of food-getting.

UNIT NINE

UNIT 9

HOW DO PLANTS AND ANIMALS GET FOOD?

INTRODUCTORY EXERCISES

1. Make a list of ten or more animals that are as different from each other as you can think of. How does each animal get its food? Why do these animals get their food in different ways?

2. Name some plants to think about as you study how plants get food. If you can do so, name some very simple plants, some green plants, and some plants that are not green. How do these plants get their food?

3. What is food? Why do living things need food?

4. How is man different from other animals in his ways of getting food?

5. In your note-book write the letters *a* to *f* in a column. Then read sentence *a*, below. From the list of words choose the correct word or words to finish the sentence. Write the answer opposite the letter *a*. Do the same for the other sentences. A word may be used more than once.

animal food	*carbon dioxide*	*minerals*	*roots*	*water*
chlorophyll	*leaves*	*stomata*	*sun*	*stems*

a) The materials that green plants use to make food are .....

b) The materials for food-making are taken into the plant through .....

c) Green plants make most of their food in their .....

d) While making food, plants get energy from the .....

e) The machinery for making food in green plants consists of tiny parts of the leaf filled with .....

f) Green plants are the source of all .....

FIG. 214. Primitive man spent most of his time looking for food. As time went on, man learned how to improve his methods of food-getting. He learned to domesticate animals, to cultivate plants, and to make and use complex machinery. The machine above both cuts and threshes the wheat.

LOOKING AHEAD TO UNIT NINE

AB, THE CAVE MAN, had just returned home. He was a curious looking creature, with a narrow head, a long upper lip, almost no chin, and a heavy body. In one hand he carried a club, and in the other hand the body of a rabbit. It was evening, and Ab was tired. Since dawn he had been hunting. All day long he had been looking for something that he could catch and kill. Ab was hungry, and his family was hungry, too.

Ab and his family were always hungry. It seemed as if they could never get enough to eat. And now Ab was coming home with just enough food to give them all a little taste. Tomorrow he would get up early and try it again. He hoped he would have better luck. When he was lucky, he ate; when he was unlucky, he went to bed hungry. All of his waking hours were spent hunting for food.

FIG. 215. Notice how differently each of these kinds of animals gets its food. The eagle with its sharp, powerful claws has captured a rabbit and will tear it to pieces with its sharp, hooked beak. The potato bugs are crawling over potato plants, stopping here and there to chew the green leaves.

Perhaps you think that food-getting is no longer the hard problem that it used to be. Go out-of-doors some bright spring morning and watch all the plants and animals you can find. What are they doing? How are they spending most of their time?

Bees are going from flower to flower looking for pollen and nectar. Caterpillars are eating the leaves of plants. Robins are hunting for earthworms and insects. Spiders have placed their webs where insects will get caught in them. Small birds are darting in and out of trees or hopping about on the ground catching insects. Hawks are soaring over the meadows looking for frogs, mice, and small snakes.

The whole world seems to be alive with hungry animals hunting for food. Do you wonder that a scientist once said, "All life is a struggle to find things to eat and to keep from being eaten"?

Of course, the life of man has changed greatly since the days of Ab, the cave man. No longer does each man have to hunt food for himself and his family. Most of our food is raised by the farmer and prepared for us in canning factories, bakeries, meat-packing plants, and other places. But after the food is grown and prepared for us, we still must work to get money to buy this food. Men and women have to solve the problem of getting enough food to keep themselves and their children alive. It is just as important a problem to them as it is to the other living things of the world.

Horses, tigers, fish, frogs, mice, and men and women must have food to eat. Each of them has its own way of finding and capturing food and of getting food into its body. In this unit you will discover why animals are different in their methods of food-getting.

But, as you know, animals are not the only living things. Plants are living things, too; therefore they must have food. Every living plant that you see is struggling to get food just as hard as the animals are struggling. But plants cannot move around in search of food or seize food as it passes by. How, then, do plants get food? This unit will tell you. And it will show you that if plants did not get food, you would not get food, either.

FIG. 216. A little acorn grows into a big oak tree. How does the tree get the food it needs to grow?

FIG. 217. You could spend more than a lifetime studying the plants and animals you see every day. And the more you studied them, the more interesting they would become to you. Science should give you new eyes with which to see and understand things that you never before saw and understood.

Problem 1:
HOW DO ANIMALS GET FOOD?

HOW DO ANIMALS TAKE FOOD INTO THEIR BODIES? If you could watch rabbits, bears, fish, grasshoppers, ants, cows, cats, and other animals actually get their food and eat it, you would have many interesting stories. These stories would give you the answer to Problem 1. Keep your eyes open when you are out-of-doors and see what you can discover about the many different ways animals get food. The best way to learn is to discover things for yourself.

In the meantime, let us see what you can find out by watching some animals in the school-room. But, first of all, you should have a general idea of what to look for. These questions will help you to do this.

1. What kind of animal is it?
2. What kind of food does it eat?

3. How does the animal find its food? Does it find food by sight, smell, hearing, touch, or taste, or by using several of these senses?

4. How does it capture its food? Does it creep up on its prey, lie in wait for it, trap it, chase it, or simply walk up to it?

5. What parts of the animal's body help it to get its food? Does it use wings, legs, claws, teeth, bill, tail, beak, pincers, etc.?

6. How does the animal get the food into its body?

EXPERIMENT 41. *How Do Animals Take Food into Their Bodies?* (*a*) Make homes in your classroom or in your own home for as many different kinds of small animals as you can get. Animals that you might get are toads, frogs, caterpillars, grasshoppers, crickets, crayfish, chameleons, turtles, etc. Arrange water, plants, and soil so that the surroundings will be as comfortable and as natural as possible.

Offer the animals different kinds of food and watch them eat. Keep a record of the foods that are eaten by each animal. Try to answer the questions given on page 300. Perhaps you can draw pictures of the different animals eating. Talk to your teacher about taking care of your animals and feeding them.

b) Watch outdoors as many kinds of animals as you can to see just how they eat. Make notes and report to your class what you learned. You might watch squirrels, cats, dogs, birds of different kinds, cows, horses, rabbits, grasshoppers, ants, butterflies, flies, fish, sheep, pigs, etc.

WHY DO ANIMALS HAVE DIFFERENT WAYS OF GETTING FOOD? You have watched animals often enough to know that they have different ways of taking food into their bodies. When you stop to think, you can see why this is true. Each animal has its own kind of *structure;* that is, each animal has various parts to its body. These

FIG. 218. How a frog captures flies

structures have different shapes and are joined together in different ways in different animals. For example, the tongue of a frog or a toad is fastened at the front of the mouth. Therefore the toad can flip out its tongue a long way to catch flies. The tongue of a lion is very rough and horny. It is so rough that it can scrape flesh from a bone. Each of these animals uses its tongue to get food, but the ways of using the tongue are different because their tongues are made differently.

The structure of the body of an animal determines largely what food it can get and how it can put this food into its body. A woodpecker has a keen sense of hearing; it can hear worms and insects eating the wood of trees. It has a long strong bill with which it can make holes in the trees to get the worms and insects. It also has a long slender tongue that it can stick into the holes to pull out the insects. A butterfly, on the other hand, has a long, hollow, tube-like structure called a *proboscis*. The butterfly sticks its proboscis down into flowers and sucks the nectar from them. If you study the structures of other animals, you will see

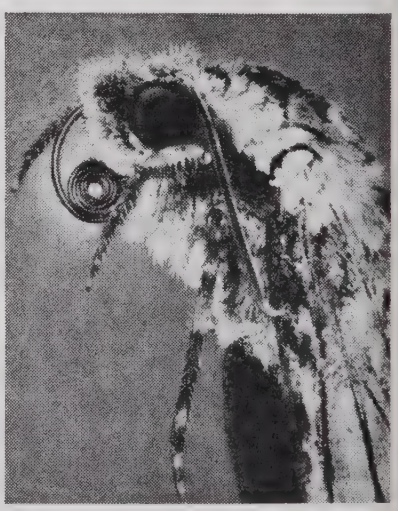


FIG. 219. A moth, like a butterfly, has a proboscis for sucking nectar from flowers.

that the ways they get their food and the kinds of food they eat depend almost entirely on their structure.

As you study more about animals, you will also find that there is a close relationship between the structure of an animal and the way it acts. The way each animal finds its food, eats its food, breathes, and fights its enemies depends on the structure of the animal.

Self-Testing Exercises

1. Tell some things you have learned by your own observation about how animals get food.

2. Why can different kinds of animals get different kinds of food? Give examples.

3. Give some different ways that animals use in getting food into their bodies.

FIG. 220. How does a hummingbird get food from flowers?

Problems to Solve

1. Watch a number of different animals, according to the plan given on page 300, and tell exactly how they get food and take it into their bodies.

2. Select two animals and show how the structure of each animal determines how it acts, that is, how it moves, eats, fights, and does other things.

3. Some of the following questions can be answered from your own observations. You can find the answers to the others in reference books.

a) What parts of an ant-eater's body help it to get food?
b) How does a flicker get ants from an ant-hill?

c) Why do sheep bite off grass closer to the ground than cattle do?
d) What special parts of the bodies of cats and dogs help them to slip up on their prey without making any noise?
e) What parts of its body help a giraffe to get food?
f) How does a pelican carry food to its young?
g) Why does a chicken hold its bill up in the air from time to time when it is drinking?

HOW IS MAN DIFFERENT FROM OTHER ANIMALS IN THE WAY HE GETS FOOD? You have learned that the way animals get food depends on how their bodies are made. But, when you first think about it, this does not seem to be true of man. If man wants food that he cannot catch by running after it or cannot kill because it is too large, he shoots it with a bow and arrow or a gun. Or he uses nets, traps, and fish-hooks. If he wants to eat tough or hard things, he grinds them or cooks them until they are soft. If he wants food that grows too far away, he has it brought to him in a truck or in a railroad car. When he does these things, he does not seem to be using the structures of his body.

But think again. Why can man do these things that animals cannot do? It is because man has a brain that can think. This brain is made differently from the brains of animals; its structure is different. Therefore, man can think out ways of doing things. Animals cannot think and plan as man does.

There is another way in which man is different from most animals. His hands can grasp tools and use them. Some animals, such as the chimpanzee, can grasp things almost as well as a man, but they do not have a well-developed brain to tell their hands what to do. The way

FIG. 221. The first tools man used to help himself get food were clubs and stones with which to kill animals. Then he invented spears, knives, and bows and arrows. The "cradles" shown in this picture had knives for cutting grain. Finally man invented the wonderful reapers shown in Figure 214.

man gets his food thus depends on how he is made. He has a good brain, and he has hands to do what the brain tells them to do.

Now let us see what man does with his brain and hands. How does he use them to get food? In the first place, man has tamed animals, and he raises them in or near his home. Some of these animals help him catch wild animals for food. But, more important, man uses tame cattle, sheep, chickens, and many other animals for food. If man had not used his brain to work out a plan for taming and raising animals, there would not be nearly enough meat for all the people in the world.

Man has also increased his food supply by cultivating certain plants. He found out which plants were best for food, and he worked out ways of making them grow better. He invented tractors, plows, drills, cultivators, and harvesters to help him raise and harvest large

FIG. 222. People in Maine may eat peaches from Georgia because man has learned how to ship food in refrigerator cars to keep it from spoiling.

amounts of food crops. Without the millions of acres of corn, wheat, rice, and other plants grown each year by farmers, millions of people would starve.

Then, too, man has learned how to ship food long distances. That makes it possible for people who live in one place to have food that grows best in a different place. Oranges and figs grow only in hot countries, but people all over the world can get them. By this plan we can have more kinds of food.

Man has learned how to preserve the foods that will not "keep." He heats some of them and puts them in cans. Other foods he treats with chemicals, such as wood smoke and salt, or he keeps them very cold. By preserving foods in these ways man can ship them from one part of the world to other parts, and foods can be kept to eat during times when they are not growing.

Man also prepares his food for eating. He grinds food; he mixes different kinds of food. He puts in chemicals, such as soda; and he uses seasoning, such as salt and

pepper, to make foods taste the way he wants them to taste. And of course, he cooks food to make it easier to eat and to make it taste better. Animals cannot do any of these things.

Another way in which man is different from most animals is that there is a division of labor among men. Not everyone must get his own food. A carpenter builds houses, and a tailor makes clothes for other people. For this work the carpenter and the tailor receive money to buy food that the farmers, butchers, millers, bakers, and grocers have made ready for them. Man is very different from animals in his methods of getting, preserving, and preparing food. He is different because he has a brain with which he can think.

Self-Testing Exercises

1. Explain how man's ways of getting food depend upon the structure of his body.
2. Make a list of man's ways of getting food that are different from those of animals.
3. Tell how a savage would get food in ways different from the way you get your food.

Problems to Solve

Can you think of any animals that do the following things?

1. Store food for their own use.
2. Store food for the use of their young.
3. Divide labor; some individuals get food and some do other things.
4. Keep other animals for food.
5. Travel long distances to get food.
6. Grow plants for food.
7. Keep food in "cans."

FIG. 223. Animals use both plants and animals for food. Squirrels live largely on nuts and other seeds of plants. Lions and tigers catch antelope, buffalo, deer, and similar animals.

WHAT DO ANIMALS USE FOR FOOD? When scientists began to think carefully about the foods of animals, they discovered a strange fact. Perhaps you have discovered this. Let us see what this strange fact is by first thinking about the kinds of food that animals eat.

Some animals, such as horses, elephants, cows, sheep, squirrels, and rabbits, eat only plants or parts of plants. A horse eats the leaves of grass and other plants when it is in a pasture. In the stable it is given hay, which is the dried stems and leaves of plants, and corn and oats, which are the seeds of plants. The food of cows and sheep is much like that of horses. Rabbits eat the tender leaves of plants; they also eat grain, such as corn and wheat, when they can get it. These animals and others that live entirely on plant food are called *herbivorous*, or "herb-eating," animals.

But not all animals are herbivorous. Some kinds live almost entirely on the bodies of other animals. These kinds are said to be *carnivorous*, or "meat-eating," animals. Probably you think first of the cat family or the dog family when we mention meat-eating animals. What do cats eat? Tame cats eat some plant foods, such as bread and cooked vegetables. But they usually prefer

animal food, such as beef, pork, mice, rabbits, and birds. Animals that belong to the dog family, such as wolves, foxes, and coyotes, eat about the same kinds of food as the cat family.

Now let us look again at the food of the carnivorous animals. Lions, tigers, and wolves eat deer, rabbits, and other animals. Some birds eat insects and worms. But the deer, rabbits, insects, and worms live on plants. Have you already guessed the important fact that scientists have discovered about the food of all animals? *All animals get their food directly or indirectly from plants.* At first this statement does not seem to be true, but if you will trace back the food of two or three different kinds of meat-eating animals, you will find that the statement is indeed true.

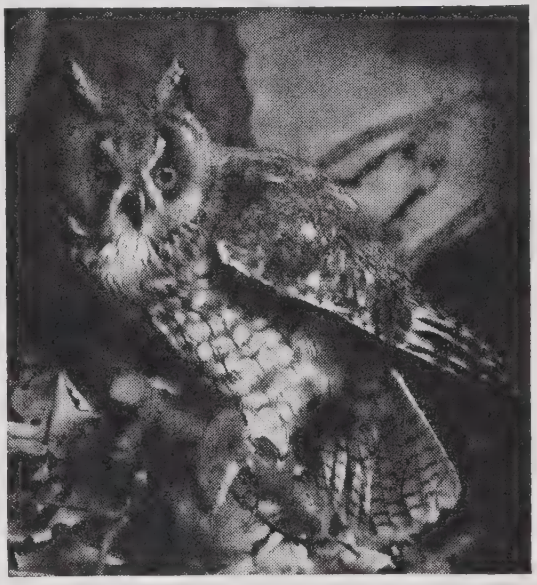


FIG. 224. Owls feed on mice and other small animals. What name do we give this kind of animal?

Let us take the case of a man eating a fish as an example of an interesting "food chain" that leads back to plants. Many large fish eat smaller fish and insects. Most insects eat plants, or they eat other insects that eat plants. Small fish eat small water animals. These small water animals eat still smaller water animals that eat the tiniest kinds of plants. Owls eat mice, and mice eat plants. So, in each case, we find that the food of all animals can be traced back to plants.

Self-Testing Exercises

1. What is an herbivorous animal? Name three.
2. What is a carnivorous animal? Name three.
3. Why do we believe that animals cannot live without plants?
4. Show that one of the carnivorous animals you named in Exercise 2 really depends on plants for food.

Problem to Solve

There is a word used by scientists to describe animals that eat both plants and animals. See if you can find this word and make a list of animals of that kind.

Problem 2:
HOW DO GREEN PLANTS GET FOOD?

WHAT KIND OF FOOD DO PLANTS USE, AND WHERE DO THEY GET IT? Plants do not move from place to place; they have no eyes and ears, no noses, and no mouths; and they cannot make noises; therefore, we often forget that they are just as much alive as we are. But plants grow and die; they produce other plants like themselves; they must have air to stay alive. Since plants are alive, they need food just as much as animals need food. Without food, plants cannot stay alive and cannot grow.

FIG. 225. A corn seed needs food to develop roots and stem.

If you ask people the question, "Where do plants get their food?" many of them will answer you in this way: "Plants get food from the soil through their roots." Now let us see if that is the way a scientist would answer the question.

FIG. 226. A grain of corn put into the ground in May grows into a plant several feet high by August.

First, you will want to know what food is. Food is any material that can be used by a plant or an animal to make new material like itself, and to supply the *energy* needed by the plant or animal to carry on its activities. In other words, plants must have materials to make bark, wood, roots, leaves, flowers, seeds, and all other parts of the plant. They must also have energy to make these parts. Animals must have food to make bone, muscle, skin, hair, and other parts of their bodies. They also must have food for energy to grow and to move. You use food for these purposes, and so do all plants and animals.

Now you already know that animals cannot use soil, water, and air for food. They cannot take these materials to build new cells, and they cannot use these materials for energy. But animals can use the bodies of plants for food. In other words, plants have food materials in them. Our problem is to discover where the plants get these food materials.

Potatoes, as you know, are a good source of food. They contain a food known as *starch*. (If you wish, you can easily show that this is true. Put a drop of iodine on a slice of potato. As you learned on page 161, starch turns blue or black when iodine touches it.) Now how does the potato plant get starch? Potato roots grow down

into the soil, and potato leaves grow up in the air. Is there starch in the soil or in the air? The chemist tells us that he cannot find any starch in either soil or air. He tells us, however, that he can find in the soil and the air substances that contain the same elements that are in starch.

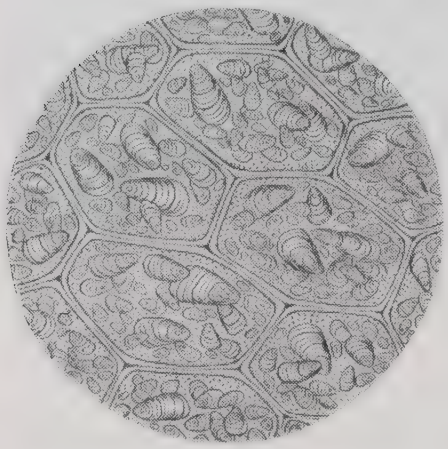


FIG. 227. Potato cells with starch grains in them, as seen with a microscope

These facts seem to tell us that the plant takes substances from the air and soil and manufactures starch from them. In other words, the plant makes food (starch) from raw materials that it gets from the soil and air. This starch is used by the plant for food. Now you can see why the answer, "Plants get *food* from the soil through their roots" is not correct. The true answer is that plants get materials from the soil and air from which they can make food.

Starch is only one kind of food made by plants. Another kind of food is *sugar*. Sugar and starch are two different kinds of compounds, but they are made from the same elements joined together in almost the same way. Starch and sugar are called *carbohydrates*. You will soon see why they are given this name.

WHAT RAW MATERIALS ARE NEEDED BY GREEN PLANTS TO MAKE FOOD? You have learned that plants make starch and sugar, and that starch and sugar are called carbohydrates. What do the plants use to make carbohydrates? To answer that question, the first thing to do is to find out what carbohydrates are made of.

Experiment 42. *What Are Carbohydrates Made Of?* (*a*) Put a small amount of dry starch in a test-tube. Heat the starch until it turns black. At the same time watch the sides of the test-tube. What do you see on the sides of the test-tube as the starch begins to turn black? Heat the starch until no further changes take place. What is left? (What common element is usually black?)

b) Do the experiment again, using sugar.

This simple experiment shows that carbohydrates contain the element carbon. The simplest way we know to find out whether a substance contains carbon is to heat it. As you learned on pages 163 to 165, some compounds separate into elements when they are heated. Many compounds that contain carbon will give off the carbon when they are heated. The black material left in the test-tube in Experiment 42 was the element carbon. This carbon came out of the starch and the sugar when you heated them.

As you heated the starch and sugar, you probably noticed little drops of liquid on the inside of the test-tube. You cannot be sure what the liquid is, but chemists can prove that it is water. When starch and sugar decompose because of heat, they give off both carbon and water. Now you see that carbohydrates are compounds of carbon and water. *Carbo* is the first part of the word carbon; *hydrate* comes from a Greek word meaning water. So the word "carbohydrate" tells us what materials are found in carbohydrates. You already know that water is a compound composed of hydrogen and oxygen; therefore you have found out what carbohydrates are made of. They are made of three elements—carbon, hydrogen, and oxygen.

To make carbohydrates, plants must have raw materials that contain the three elements—carbon, hydrogen, and oxygen. You know that water is made of hydrogen and oxygen; therefore, water gives the plant two of the elements it needs. But where does the carbon come from? Air, you know, is a mixture of gases. One of these gases in the air is the compound, carbon dioxide (CO_2). From the carbon dioxide in the air the plant gets the third element it needs—carbon. From the water in the soil and from the air around the leaves and stems, the green plant gets the raw materials to make starches and sugars for food.

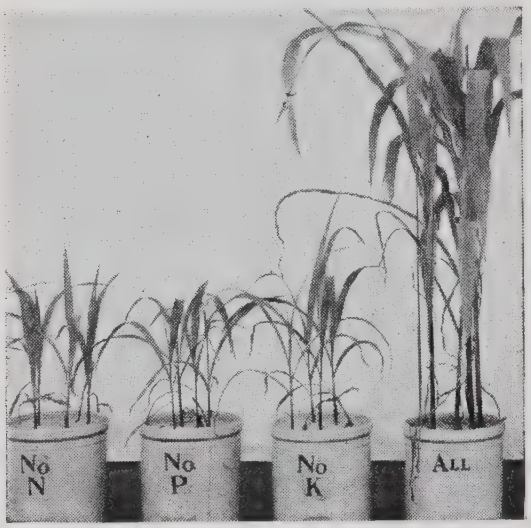


Fig. 228. Experiments show the importance of materials in the soil. The plant grown in soil containing nitrogen, phosphorus, and potassium grew twice as large as the others, which lacked one of those minerals.

But starch and sugar are not the only kinds of food that plants make. There are other kinds of food made by green plants, and these other kinds need some different raw materials. Let us see what else the plant needs besides carbon dioxide and water.

In Unit Eight you learned that in your body there is about a pound of phosphorus and about enough iron to make a good-sized nail. You also learned that your bones are made largely of calcium. As you know, iron, phosphorus, and calcium are elements. They are found in compounds that are called *minerals*. We get minerals from the food we eat, and all our food comes from green

plants. Therefore, green plants must have minerals as well as carbon and water to make food. Did your doctor or your mother ever tell you to eat more of such foods as celery, tomatoes, lettuce, and squash? Do they insist that you drink plenty of milk? Everyone should use plenty of foods like these because they contain minerals that the body needs. Where does the plant get these raw materials—the minerals? Let us find out by an experiment.

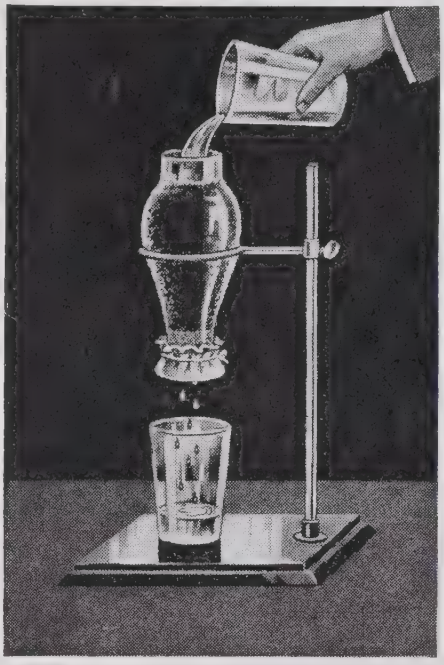


FIG. 229. Apparatus for Experiment 43a

EXPERIMENT 43. *Does Soil Contain Minerals That Will Dissolve?* (*a*) Fasten a piece of fine wire screen or cheese-cloth over the small end of a lamp chimney. Support the chimney over a clean tumbler (Figure 229).

Put about an inch of fine sand into the chimney. On top of the sand put rich, black soil almost to the top of the chimney.

Pour a tumblerful of rain-water or distilled water on top of the soil. Collect the clear water that seeps through the soil and sand into the tumbler. If the tumbler is not almost full of water, pour some more water on the soil. This water in the tumbler will be like the soil water around plant roots.

b) Boil the soil water away or allow it to evaporate from a shallow dish. Is anything left in the dish?

c) Evaporate an equal amount of rain-water or distilled water from a clean dish. Is any material left in the dish? Where did the water that you evaporated in part *b* get the material it left behind in the dish?

The whitish or brownish material left in the dish after the soil water had evaporated was composed of minerals. These minerals dissolved in the water as it soaked through the soil. Dissolved minerals are absolutely necessary to plants in making food and in growing. They are also necessary for animals and for people. We get the minerals we need when we eat plants or when we eat meat, milk, and eggs from animals that eat plants. The plants get the minerals from the soil.

Self-Testing Exercises

1. How do we know that plants make starch?
2. What uses must a material have to be called a food?
3. Why are starch and sugar called carbohydrates?
4. From what compounds do plants get the elements in starch and sugar?
5. What are minerals? Where do plants get minerals?

HOW DO PLANTS GET WATER AND MINERALS FROM THE SOIL? In Problem 1 you learned that the way an animal gets food depends on how it is made. The way plants get food depends on how they are made, too. They have to use their parts to get raw materials and to change the raw materials into food for themselves and for animals. Let us see how the parts of plants help them to make food.

The kinds of plants we know best are called seed plants. They have roots, stems, leaves, flowers, and seeds. Roots, stems, and leaves are made in such a way as to help these plants get raw materials and make food. To discover how seed plants get raw materials for food, let us see what we can learn about the roots of plants.

Roots have several uses. One important use of roots is to hold the plant in place, or to anchor it. If you ever tried to pull up a large weed or a small tree, you found that the roots have a very strong hold in the ground. However, roots have another very important use. They get water and dissolved minerals for the plant. Let us see how roots are made; then we can understand how they get these raw materials.

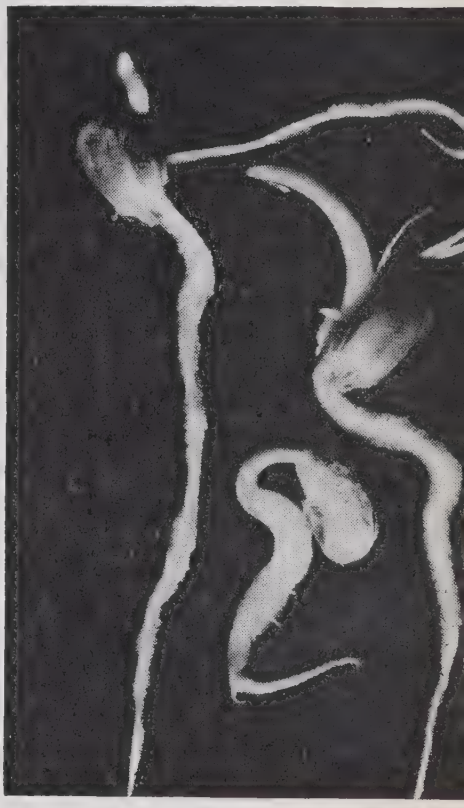


FIG. 230

EXPERIMENT 44. *What Are Root Hairs?* Place a piece of a blotter or several pieces of towel paper on a piece of window glass about three inches square. Lay several radish seeds or other small seeds on the paper. On top of the seeds lay another piece of glass the same size as the first.

Fasten the squares of glass together with rubber bands. Lay the whole apparatus in water overnight. Then set the apparatus on edge in a pan or dish that contains one-half inch of water. Put the pan in a warm place until the seeds begin to grow.

When the roots are about an inch long, study a single plant and its root through the glass. The white fuzz along the root is composed of tiny *root-hairs* (Figure 230). Where are the root-hairs longest? Where shortest? Are there any at the very end of the root? Make a drawing to show what you have noticed about the root-hairs of your plants.

Put the plants back as they were, and look at them from day to day. Do more root-hairs grow? Where?

The tiny white root-hairs that you have seen are hollow tubes that grow from the cells on the outside of the root.

They are filled with the watery sap of the plant. Root-hairs grow on only one part of a root, the part within an inch or so of the end. They grow very close to the tiny pieces of soil. There are so many of them and their walls are so thin that they are able to soak up all the water and minerals a plant uses.

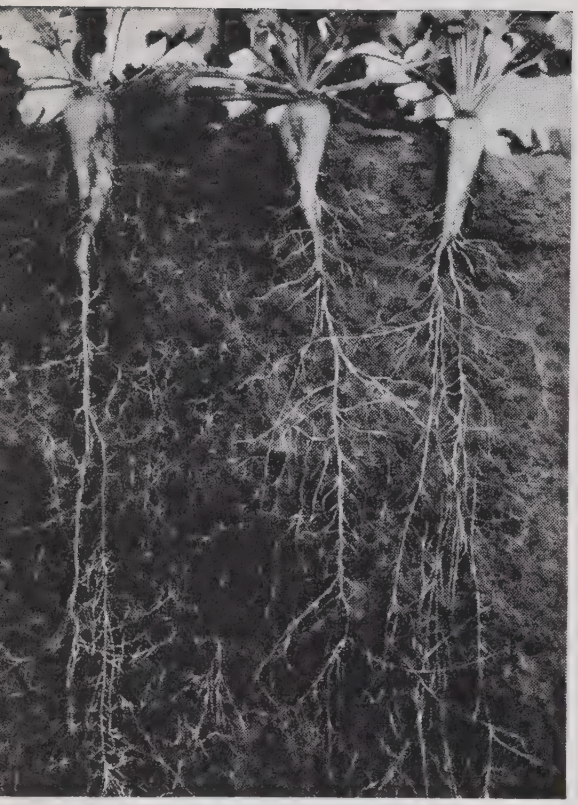


FIG. 231. The tap-root systems of sugar beets

EXPERIMENT 45. *What Is a Plant's Root System Like?* Find some common plant like a dandelion or a corn plant. The day before you do the experiment pour plenty of water around the plant so that the soil is thoroughly wet. Dig the plant up with a trowel or spade, and do your best to get all the roots. Leave most of the soil clinging to the roots. Then put the plant in a pan of water, and wash the soil gently from the roots so that the fine hair-like roots are not broken.

Notice the main root of the plant, the smaller roots that join the main root, and the still finer branches of the small roots. Look for root-hairs near the tips of the smallest roots. You will probably not see them, but you will see a little layer of soil or sand held near the root tip by the root-hairs.

Measure the length of the roots. What is the length of the entire root system? Did you get all of it, or were some roots broken off? Why does the plant need so many roots?

Make a drawing of the root system as you have found it. Label all the features you have noticed.

Now what did you learn about the root system of a plant? If you studied a dandelion root, you saw that it

had a main root, or *tap-root*, from which many smaller roots branched off. If you studied plants such as grass, wheat, or corn, you saw many *fibrous roots* that were all about the same size (Figure 232). Thousands of small rootlets branched off from these fibrous roots.

In many plants the root system is larger than the part of the plant above the ground. A corn plant, for example, may have fifteen or twenty main roots. From these main roots there may be several thousand smaller roots reaching out through as much as 200 cubic feet of soil.

FIG. 232. The fibrous root system of grass plants

The larger roots and even the smaller roots have a thick covering that keeps them from taking in much water. Thus, in order to take in water, each plant has millions of root hairs such as you saw on the roots of the little radish plants in Experiment 44. When a plant is dug up, many of the root-hairs break off and remain in the soil.

You can see now why it is hard to move a plant to a new place. No matter how careful you are, many small roots and root-hairs are broken off. The plant cannot take in much water until it grows new root-hairs. When a gardener moves a plant, he often cuts off some of the branches and leaves. He does this because water evaporates from the leaves. With fewer leaves, more water will stay in the plant until new root-hairs can grow and take in water from the soil.

HOW DO WATER AND MINERALS REACH THE LEAVES? Big factories must have some way of carrying raw materials from one part of the factory to other parts. Trucks and railroad cars bring the materials to the doors. Derricks, cranes, and trucks carry the materials to the machines and furnaces that make things. The green plant, too, must have a way of carrying raw materials all through it.

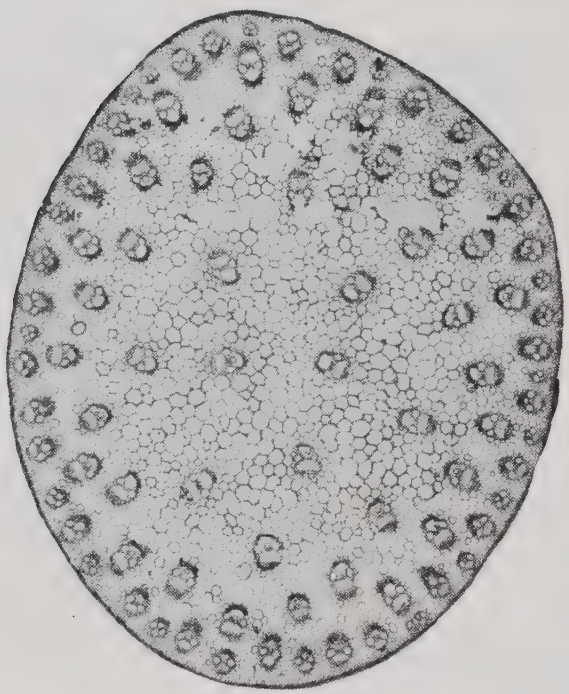


FIG. 233. A thin slice of a corn stem, magnified to show the scattered bundles of cells that carry water and food

When the water and minerals get into the roots, they must travel on up through the plant. They must get up to the leaves, because the green leaves are the food factories. The raw materials that the plant uses to make food—carbon dioxide, water, and minerals—must get into the leaves.

EXPERIMENT 46. *Where Are the Water-Carrying Tubes of Plants?* (*a*) Put the stem of a freshly picked daffodil or a white carnation into some water that is well colored with red ink. Cut the lower ends off a piece of celery and a small corn plant and put these in colored water, too. Leave these plants in the liquid for about a day. Into the inky water put also the leafy twig of a maple tree, and leave it for a day.

Can you see where ink has passed into the flower or leaves? Hold the leaves up to the light and compare their color with

that of untreated leaves. Can you see little *veins* that have turned pink? Cut across the stems of the plants. Can you see where the ink colored the stems red? With tweezers or any sharp instrument pick the stems to pieces and follow the red streaks up through the stems to the leaves.

b) With a pair of tweezers remove the soft, white material carefully from a dry corn-stalk. Leave the tough threads unharmed. See how the threads are arranged.

You can understand better what you saw in the experiment if you look at the cut end of a stem under a microscope. Figure 233 shows how one kind of stem looks. Do you see some round bundles of cells? These are called *vascular bundles.* Some of the cells in each bundle are very tough and hard so that the bundles are strong (Figure 234). In one part of each bundle the cells are hollow tubes joined together, so that the water can pass rapidly through them up to the leaves. In Experiment 46 the red ink went up through these tubes in the vascular bundles.

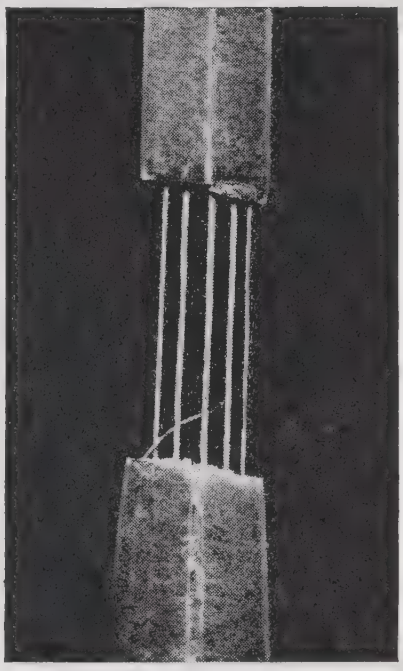


FIG. 234. In the celery stalk the vascular bundles are arranged in a circle.

The tubes that carry water upward in trees are in the wood just underneath the bark. The cells that carry food downward from the leaves are in the part of the bark that is next to the wood. Do you see that a tree has two sets of special cells in its *circulation system?* One set carries water and minerals from the roots to the leaves; the second set carries food down to the stem and roots.

Look carefully at a green leaf. You will see that it has veins all through it. In the leaves of some plants, like maple trees, beans, and geraniums, these veins form a network. In grass leaves and corn leaves the veins run parallel to each other. Often you can see the veins more clearly by holding the leaves up to the light. These veins are really the vascular bundles of the leaves. In Experiment 46 you probably noticed that the red streaks ran right up through the stems into the leaves. Every part of a leaf is very close to a vein. Thus every cell of a leaf is very close to a "water pipe." The veins also form a framework to help hold the leaf out in the sunlight.

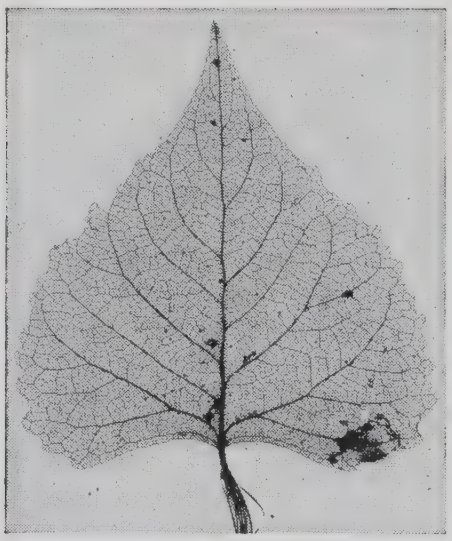


FIG. 235. A network of veins in a poplar leaf

Self-Testing Exercises

1. Tell the story of a particle of water that traveled all the way from the soil to a leaf.
2. Tell the story of a particle of sugar made in a leaf as it traveled all the way from the leaf down to a root to help the root grow.
3. Of what use to a celery plant are the "strings" you get between your teeth when you eat tough celery?

Problems to Solve

1. Why does a plant usually die when the stem is broken?
2. Farmers sometimes kill trees by "girdling" them. To girdle a tree, the farmer cuts out a rather deep ring all around the trunk of the tree. Why does the tree die?

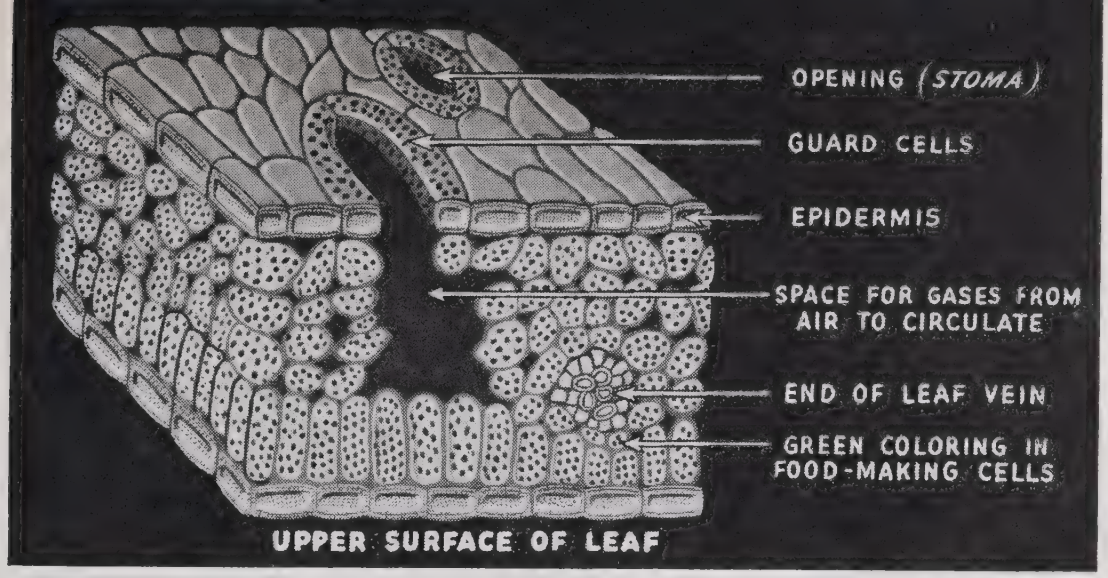


FIG. 236. This drawing shows how the cut edge of a leaf would look if it were enlarged several hundred times.

HOW DOES CARBON DIOXIDE GET INTO A LEAF? You have now learned how the raw materials from the soil get into the plant and up to the leaf factory. But the leaf factory must also have carbon dioxide to supply the carbon in the carbohydrates they make. This carbon dioxide, as you know, comes from the air that is all around each leaf of a plant. Let us see how a leaf is constructed to let the carbon dioxide from the air pass into the food-making cells.

Look carefully at Figure 236. You can see the end of a vein that brings water to the leaf and carries food away. All around the outside of the leaf is a layer of clear cells called the *epidermis*. Light can shine right through the cells of the epidermis into the inside of the leaf. On the outside of the epidermis is a layer of a waxy material that is waterproof. This layer of material helps to keep too much water from evaporating from the cells of the epidermis.

Next look at the part of the leaf between the upper and lower epidermis. The cells in this part have many little green bodies in them. These green bodies make the leaf look green. The cells with the green bodies are the

ones that make the food. There are air spaces around most of these food-making cells. And do you see, in the lower epidermis, the little openings that lead from the air spaces out into the atmosphere? Let us examine a leaf with a microscope and see these little openings.

Experiment 47. *What Does the Epidermis of a Leaf Look Like through a Microscope?* Your teacher will show you, through a microscope, the epidermis that has been peeled off some common leaf, like that of a geranium or an onion. Look at it carefully and look also at Figures 236 and 237.

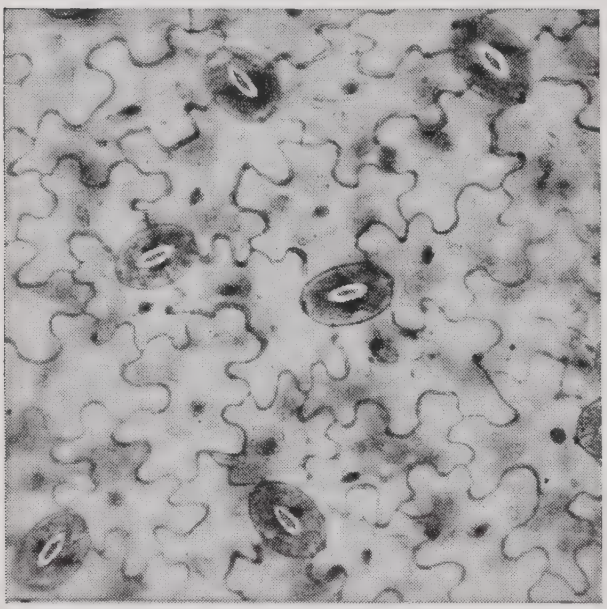


Fig. 237. Epidermis of a geranium leaf, as seen through a microscope. Six stomata are shown.

In most leaves the colorless cells of the epidermis are of irregular shapes. Can you see them? In some places there are pairs of tiny bean-shaped cells. Between each pair of these cells is an opening through the epidermis. Look at the pair of cells and the opening between them in Figures 236 and 237.

The pairs of cells are called *guard cells*. The little opening between each pair of guard cells in the epidermis is called a *stoma*. (The plural is *stomata*.) "Stoma" is the Greek word for mouth. Notice that each opening in Figures 236 and 237 is shaped like a little mouth. The carbon dioxide from the air enters the leaf through these little mouths.

Self-Testing Exercise

Close your book and see if you can make a diagram of the structure of a leaf. Show the epidermis on top and bottom, a vein, some stomata, guard cells, and food-making cells. Put in some arrows to show where the carbon dioxide enters the leaf. Label each part of the leaf.

HOW DO LEAVES MAKE FOOD? In the leaf we now have the raw materials that the plant needs to make food—water and minerals from the soil, and carbon dioxide from the air. What happens next? By what magic can the plant put carbon dioxide, water, and minerals together to make apples, melons, and nuts —to say nothing of the roots, stems, and leaves of the plant itself? Everything in the plant is made from water, carbon dioxide, and minerals.

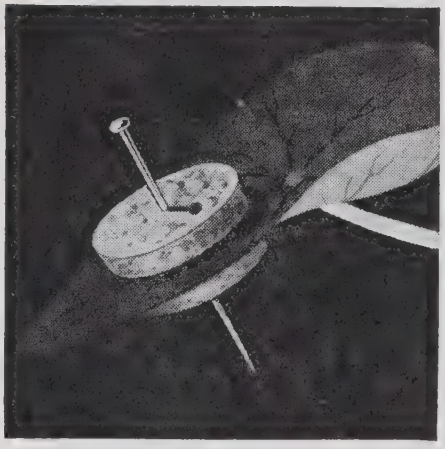


FIG. 238. Experiment 48

No one understands exactly how leaves manufacture food. Scientists know that leaves are able to make carbohydrates (sugar and starch) out of water and carbon dioxide. But just how the leaves do this the scientists do not know. We can, however, learn something about what happens.

EXPERIMENT 48. *Do Leaves Need Light in Order to Make Starch?* Obtain a healthy nasturtium or geranium plant. Place it in the dark for at least two days. Then pin two thin pieces of cork or black paper on the two sides of a leaf as shown in Figure 238. (It is well to fix two or three leaves this way.) If the leaf is too heavy to hold itself up, prop it up. Set the plant in bright sunlight for several hours. Then break off the

leaf, and dip it into boiling water for a short time. The heat kills the leaf and makes the rest of the experiment work better.

Next put the leaf into alcohol to soak the green color out of the leaf. Set the vessel of alcohol in a larger vessel of boiling water until the green color is gone from the leaf. You may need to get fresh alcohol to get the color all out. Now soak the leaf in a weak solution of iodine. Then spread it out on a piece of glass or cardboard.

Does part of the leaf turn bluish or black instead of brown? Which part? What substance does this show is in the leaf? (See page 311 if you have forgotten.)

Many experiments somewhat like the one you have done show that leaves make sugar and starch only when they are in the light. If green plants are kept in darkness for a long time, they will die. They die because they can no longer make food. Other experiments show that the green coloring in leaves helps make food.

Figure 236 shows that the green material is in the form of little green bodies scattered through the central part of the leaf. They make the entire leaf appear green. This green material is called *chlorophyll.* Plants that do not have chlorophyll cannot make carbohydrates. Many experiments have been done by scientists to prove that this is true.

You see now that four conditions are necessary before a plant can manufacture food: (1) The plant must have a supply of water. (2) The plant must have a supply of carbon dioxide. (3) The plant must be green (contain chlorophyll). (4) The plant must be in the light.

Now let us get a clearer picture of what happens in a green leaf in the sunlight. The green leaf is a factory. It makes a product (food) from raw materials (carbon

dioxide and water). In other words, the green leaf makes a chemical change take place in the raw materials. By this change the raw materials are made into a new material. The change is brought about by the protoplasm and the chlorophyll. Light must shine on the chlorophyll or the change will not take place. The chlorophyll is the machinery of the factory. The protoplasm inside the cells of the leaf manages and takes care of the factory and its machinery. The light from the sun furnishes the power to run the machinery.

No one knows just how chlorophyll and protoplasm make sugar. We do know that the carbon dioxide and water are changed to sugar. And we do know that this change takes place only when light shines on the leaf. Scientists call this particular chemical change *photosynthesis* (*photo* means "light"; *synthesis* means "putting together").

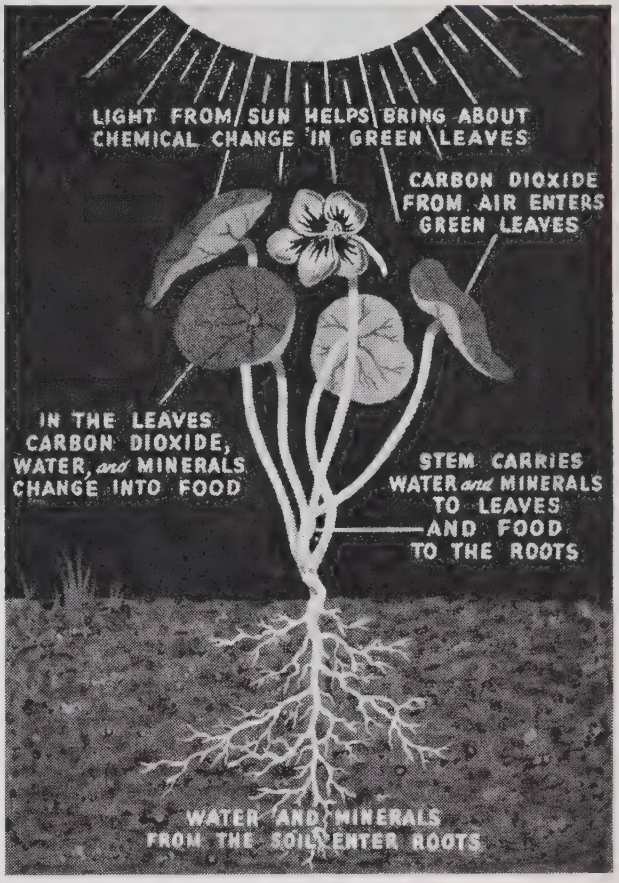

LIGHT FROM SUN HELPS BRING ABOUT CHEMICAL CHANGE IN GREEN LEAVES
CARBON DIOXIDE FROM AIR ENTERS GREEN LEAVES
IN THE LEAVES CARBON DIOXIDE, WATER, and MINERALS CHANGE INTO FOOD
STEM CARRIES WATER and MINERALS TO LEAVES AND FOOD TO THE ROOTS
WATER AND MINERALS FROM THE SOIL ENTER ROOTS

FIG. 239. The green-plant food-making factory

This chemical change that goes on in the leaf of the green plant is the most important chemical change in the world. If it did not take place, all living things would die. Neither green plants nor animals nor man with all his science can use the raw materials in the soil, air, and water for food. These raw materials must be changed to foods before living things can use them. This chemical change of raw

materials to foods can be made only by the green plant.

So far you have learned how green plants manufacture carbohydrate foods. Chemists have shown that sugar is manufactured in the process of photosynthesis. But before the sugar is stored in the leaf, it is changed to starch, as you saw in Experiment 48. This is another chemical change. At night some of the starch is changed into sugar again and moved away to the stems, roots, and seeds.

Do you know why this change must take place before the food can circulate through the plant? Refer to Experiment 3 on page 92 and you will find the reason. Only dissolved materials can move through the cells of the plant. Starch cannot dissolve, but sugar can dissolve. When the dissolved sugar reaches the roots, stems, and seeds, it is changed back again into starch. There it is stored for later use by the plant in growing. There, too, you can find it when you need some food.

When we want large amounts of carbohydrates, we look for them in the places where plants have stored them. We dig up the roots of sweet potatoes and beets and the underground stems of white potatoes. We gather the seeds of corn, rice, and wheat. To get sugar, we evaporate the sap of sugar cane, sugar beets, and maple trees. From these and other plants come all the carbohydrates we eat.

But not all kinds of food are carbohydrates. Other kinds, about which you will learn later, are called *fats* and *proteins*. Plants change carbohydrates into fats and store them in such seeds as peanuts, olives, cotton seed, and pecans. Plants also make proteins out of carbohydrates and minerals. Scientists do not know

just how the plant is able to change carbohydrates into fats and proteins.

Self-Testing Exercises

1. What materials are needed by plants to make carbohydrates?
2. What material must be in the leaf to make it possible for the plant to carry on photosynthesis?
3. How do we know that light is necessary for photosynthesis?
4. Why can only green plants make carbohydrates?
5. How do you know that photosynthesis is a chemical change?

Problems to Solve

1. Use iodine to test a number of vegetables and fruits to see if they have starch in them.
2. Ask the teacher for some Fehling's solution. Fehling's solution is used to make tests for certain kinds of sugar. Some kinds of sugar, like cane sugar, do not affect it.

Fill a test-tube one-third full of the solution and put in a very little corn syrup. Heat the liquid. Any greenish or yellow or red color when you heat the solution shows that there is some sugar in the material you are testing. Mash some bread in a little water. Pour off the water and test the bread for sugar. Test a number of other foods and fruits for sugar.

3. Grow two pots of plants from seeds. Keep one pot in a dark place and the other pot in the sunlight. In which pot can you see more chlorophyll? What do you think this experiment shows about chlorophyll in leaves?
4. Some plants have leaves that are spotted. Parts of the leaf are green, and other parts are nearly white. If these leaves were tested for starch, what would you expect to find? Why?

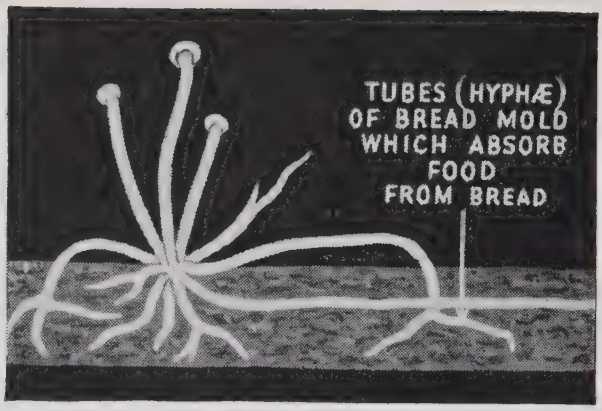


FIG. 240. This drawing shows how tiny thread-like parts of bread mold, called hyphae, go into the bread and absorb food for the mold plant.

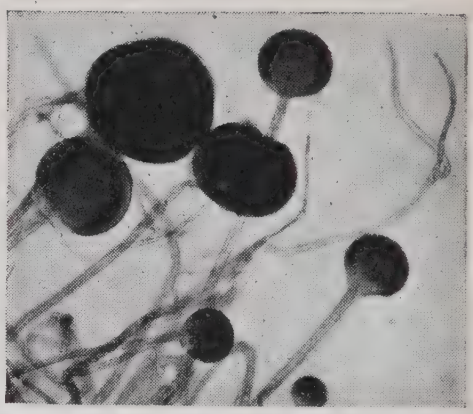


FIG. 241. Bread mold under the microscope. The black balls are full of particles that will grow into new plants.

Problem 3:

HOW DO PLANTS THAT ARE NOT GREEN GET FOOD?

YOU learned in Problem 2 that plants must have chlorophyll to make food. Many plants do not have chlorophyll. You have seen or heard of bread mold, bacteria, yeast, mushrooms, and mildew. These are all plants that cannot make their own food. They get food, as animals do, from other living things or from dead things. Such plants are called dependent plants because they depend on other things for food.

EXPERIMENT 49. *How Does Bread Mold Get Food?* Put a piece of wet blotting-paper in the bottom of a dish with a tight cover. Place a fresh slice of bread on the paper. Shake some dust from a dust cloth on the bread. Cover the dish tightly and set it in a warm place.

Look at the bread each day. Soon you should see a white, cottony material growing over the surface of the bread. After a time, black or yellow or green material will appear on the white mass. This colored material is made up of tiny balls filled with particles that will grow into new mold plants when the balls break open and the particles scatter.

Bread, as you know, is made from flour, and flour is made of wheat, which grows on green plants. The bread mold sends tiny thread-like tubes, called *hyphae*, into the bread (Figure 240). These hyphae give out chemicals that cause chemical changes in the bread and cause some of it to dissolve. The dissolved food then passes into the hyphae, much as the water and minerals get into the root-hairs of green plants. When the food gets inside, it is used by the mold for growth.

There are thousands of kinds of plants that are not green. They grow on damp bread and crackers, old leather, damp clothes, meat, milk, fence posts, old logs, and dead leaves. In fact, they grow on almost anything that has ever been alive or that has come from living things. All those plants that get their food from things that are not alive are called *saprophytes*.

FIG. 242. Indian pipe is another plant that is not green.

We think many of these saprophytes are harmful because they spoil our bread and meat, make milk sour, cause wood to decay, and discolor cloth and paper that is damp. But there are many helpful kinds of saprophytes. The yeast plants used to make bread rise are very valuable. Bacteria and molds are used in making cheese. Others are used in making linen cloth and in tanning leather. The bacteria and molds that cause the bodies

of plants and animals to decay are also very useful. They cause these dead things to separate into simpler compounds and go back into the soil. Carbon dioxide is given off into the air at the same time. Then green plants can use all these materials to make more food for the world.

FIG. 243. This apple has been destroyed by rust, a mold-like plant.

The most harmful kinds of non-green plants are the ones that get their food from living plants and animals. These plants that live on living things are called *parasites*. Some bacteria live in our bodies and make us sick. Such diseases as tuberculosis, diphtheria, and pneumonia are caused by bacteria living as parasites in the human body.

Many mold-like plants live on the leaves, stems, and fruits of green plants and do much damage. Millions of dollars worth of wheat, corn, potatoes, tomatoes, grapes, and other crops are ruined each year by the non-green plants that use them for food. The farmers call them *rusts*, *smuts*, *mildews*, and *blights*, and fight them in every way possible. Thus you see that non-green plants are like animals. They must find, in the bodies of plants or animals, food made by green plants.

Self-Testing Exercises

1. What is the reason why mushrooms and molds cannot make their own food?
2. How does a mold get food?
3. How are the hyphae of molds like the root-hairs of green plants, and how are they different?

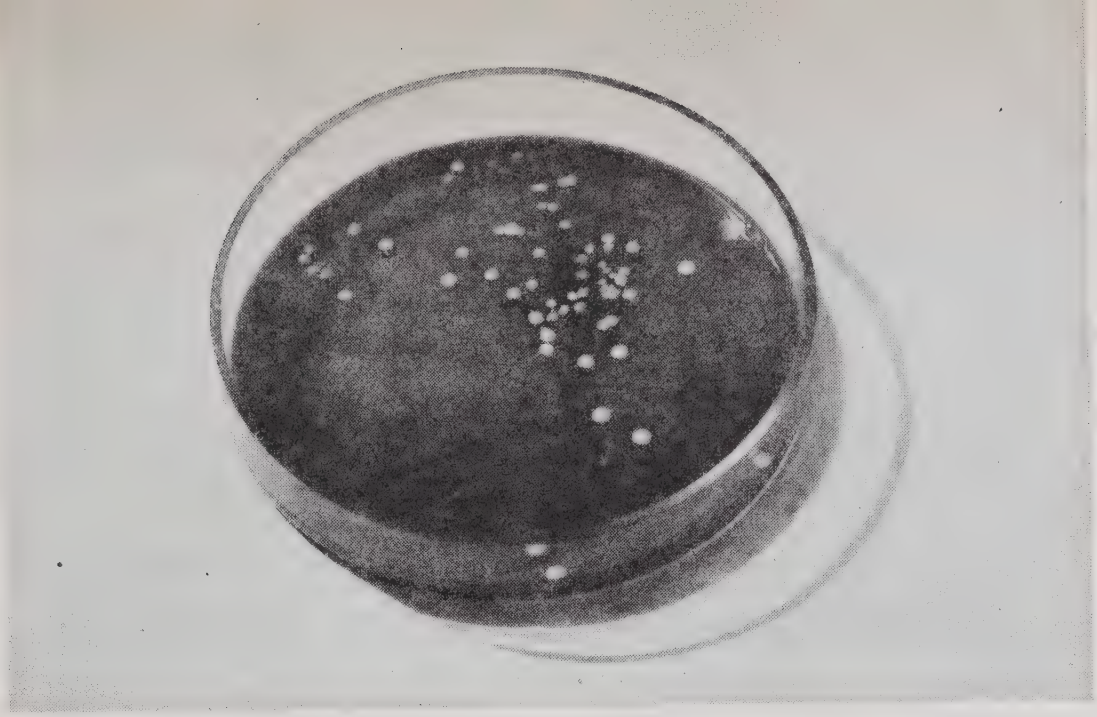


FIG. 244. A layer of gelatin in a dish exposed to the air for even a short time develops white or yellow spots in a few days. Each spot is made up of millions of bacteria that are using the gelatin for food.

4. What is the difference between saprophytes and parasites?
5. How are animals and dependent plants alike?

Problems to Solve

1. See how many different kinds of mold you can get to grow on bread or find growing on decaying fruit, etc.
2. Read about the different shapes in which bacteria grow and about some of the diseases they cause.
3. Read about plant diseases and write a composition on that topic.
4. Just after periods of damp, warm weather look for mushrooms. Find the white, mold-like hyphae that get food for the mushrooms. What do the mushrooms use for food?
5. How do bacteria and molds live when they cannot get any more food? You can find information on this in biology or botany books or in an encyclopedia.
6. Tell of some damage that dependent plants have done to you or to things that belong to you.
7. Find as many non-green plants as you can at home and in the woods. Learn their names if you can.

Problem 4 (Optional)

HOW DO PLANTS MAKE FOOD?

If you have studied the optional problems of the preceding units, you can understand more about the chemical change that takes place during photosynthesis. The chemist, of course, can write an equation to show what happens. This equation is as follows:

$$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$$

Six molecules of carbon dioxide — Six molecules of water — make — One molecule of sugar — Six molecules of oxygen

During photosynthesis, carbon-dioxide molecules from the air are passing into the leaf. Inside the leaf the carbon of the carbon-dioxide combines with water to form sugar. The oxygen of the carbon-dioxide is given off as a gas. The oxygen molecules that are given off move out through the stomata into the air. Thus, through the open stomata carbon-dioxide molecules are streaming into the leaf, and oxygen molecules are streaming out. They pass each other somewhat like two lines of bees going in opposite directions through the door of a hive.

This exchange of gases in the green plant is of the greatest value to living things. Let us see why. Animals take in oxygen and give off carbon dioxide when they breathe. Plants do the same thing. When we think of the millions of living things breathing all the time, it would seem that all of the oxygen in the air would soon be used. And this would happen except for photosynthesis.

Green plants produce more oxygen during the process of photosynthesis than they themselves can use. This extra oxygen goes back into the air and can be used by

other living things. Animals breathe in oxygen and give out carbon dioxide. The plant takes in carbon dioxide, separates the carbon and oxygen, and gives the oxygen back to the air. Because plants carry on photosynthesis, the same oxygen and carbon dioxide may be used over and over again without exhausting the supply.

Self-Testing Exercises

1. Write the chemical equation for photosynthesis and explain it.

2. Draw a diagram of the oxygen-carbon-dioxide cycle and write a brief explanation of your diagram.

LOOKING BACK AT UNIT NINE—SUMMARY EXERCISES

1. Write a one-page answer to the problem, "How Do Plants and Animals Get Food?" Be sure that you include all the most important ideas in Unit Nine.

2. Show that you know what each of the following science words means:

carbohydrates	*epidermis*	*photosynthesis*	*structure*
carnivorous	*herbivorous*	*saprophyte*	*tap root*
chlorophyll	*parasite*	*stoma*	*vein*

ADDITIONAL EXERCISES

1. If certain green water-plants are placed in an aquarium with certain small water animals and then the aquarium is sealed, both plants and animals will go on living without the addition of new food or oxygen. Explain how this is possible.

2. There is much less sap in plants in winter than in the spring. State a reason that will explain this.

3. Potatoes that sprout in the cellar have white leaves. Explain.

4. The color of the grass under a board is different from the grass around it. Find a board lying on the grass and

examine the grass to see how it is different. Explain what you see.

5. Find out how the florist makes green carnations for St. Patrick's Day.

6. Newly picked peas and sweet corn are sweeter than after they have been kept for a day. Explain.

7. Observe a horse or a rabbit eating grass. Compare the methods they use with those of the cow. Try to explain just why they use different methods.

8. Some plants such as Venus's flytrap, the sundew, and the pitcher-plant use animals for food. Find out how they capture animals.

9. Make a list of animals that (*a*) catch food by pursuing their prey, (*b*) set traps for their prey, (*c*) lie in wait until their prey is near enough to catch.

10. If you will walk around a tree and observe the position of its leaves, you will find that they are arranged so as to catch the greatest amount of light. What is the value of this arrangement to the plant?

11. Is it correct to speak of "eating sunshine"? Explain.

12. Look at different kinds of green plants in your home, in greenhouses, or outdoors to see how they place their leaves to catch sunlight. Look at tall plants, vines, and plants that grow close to the ground.

13. Find out as much as you can about where your own food is grown. Then write a paper telling what you learned; or make an oral report to your class.

14. Does washing our hands get rid of the bacteria on them? Moisten the tips of your fingers with water that has been boiled and cooled; then touch them to fresh gelatin in a dish. Do the same thing after you have thoroughly scrubbed your hands. Let the colonies develop.

FIG. 245. Some of the most important discoveries about what foods do for us have been made by experimenting with the food of animals. From the ways different kinds of food affect animals, scientists can usually tell how these foods will affect men and women and boys and girls. This picture shows a scientist with his white rats and guinea pigs that are being used to make discoveries about food.

UNIT TEN

UNIT 10

WHY DO WE EAT DIFFERENT KINDS OF FOOD?

INTRODUCTORY EXERCISES

1. Keep a careful record of the food you eat for at least a week. After each meal put down what you ate and how much. Put down also any food or candy you eat between meals.

2. What is protoplasm? Is there any protoplasm in your body? If so, where is it?

3. What are cells? Where in your body are they found?

4. Name the most important elements in your body. Name also some compounds found in your body.

5. What does your body use food for? Give several uses.

6. Tell what happens to your food from the time you eat it until it reaches the cells that use it.

7. What are vitamins? What happens to a person when his body does not get enough vitamins?

8. How do you decide what foods to eat? Do you think you have a good plan? Tell why you think it is good or bad.

9. What is the meaning of oxidation?

FIG. 246. Study this picture carefully. It gives you some good advice on what to eat. When you have completed your study of this unit, you will be able to tell why each of these kinds of food is valuable to your body. (Courtesy National Dairy Council)

LOOKING AHEAD TO UNIT TEN

SOMETIMES stories are written that tell how we will live a few hundred years from now. Often in these stories we are told that eating will be simply a matter of swallowing pills. The stories predict that scientists will discover how to concentrate foods until a single pill will give us as much nourishment as a whole dinner. Now it is true that soldiers and explorers today carry concentrated foods, but they are not pills. Pills probably will not take the place of food during your lifetime.

FIG. 247. If you eat at the school cafeteria, do you select your foods wisely, or do you just "load up" with the things you like best? What you like to eat and what your body needs may be two quite different things.

Even if the scientists could make food pills for us, we would not be very well satisfied with them. No food pill could ever take the place of roast turkey, cranberry jelly, mince pie, and ice-cream.

Eating would be still more enjoyable if we could always eat what we liked best and as much of it as we wanted. To eat a dinner of ice-cream, strawberry shortcake, cherry pie, and chocolate cake would be very pleasant. But it would not be pleasant an hour or so later when pains began to shoot through your stomach. Even if you could eat this mixture of desserts at every meal without getting a stomach-ache, such a diet would not help you to grow strong and do all of the things you want to do every day. The reason for this is that your body needs a well-balanced variety of food in order to carry on all of its activities.

All of your life someone has probably told you what you should eat. "Eat some more bread and butter." "Drink your glass of milk." "Don't forget your carrots." You have probably heard such remarks many times. Sometimes you rebelled. You did not see why you should

eat carrots when what you really wanted was a big piece of pie. But your parents had good reasons for asking you to eat different kinds of food.

Now you are old enough so that no one should need to tell you what to eat. You should know what to eat. And what is more, you should know why you need to eat certain kinds of food. When you select a meal at the school cafeteria, you should choose the right assortment of food. Perhaps you do this now without really knowing why. It is much more interesting, however, to select your food when you know how to do it scientifically. In this unit you will learn what the body does with food, the different kinds of food it needs, and how to select the foods that will keep you healthy.

Problem 1:
WHY DO OUR BODIES NEED FOOD?

If someone asked you to describe how you feel when you are hungry, what would you say? You know when you are hungry, but to tell how you know is very difficult. Did you ever wonder why you get hungry? The feeling of hunger is the signal that your body gives you to let you know that it needs more food. This brings us to another question namely, "Why does the body need food?" As you will soon learn, the body needs food for several different purposes.

The most noticeable thing that your body does is to move. You move your legs, eyes, arms, and fingers, and some people can even wiggle their ears. Movement is also going on inside your body when your heart beats and when other parts of the body move. Of course you know that the parts of the body are moved by muscles.

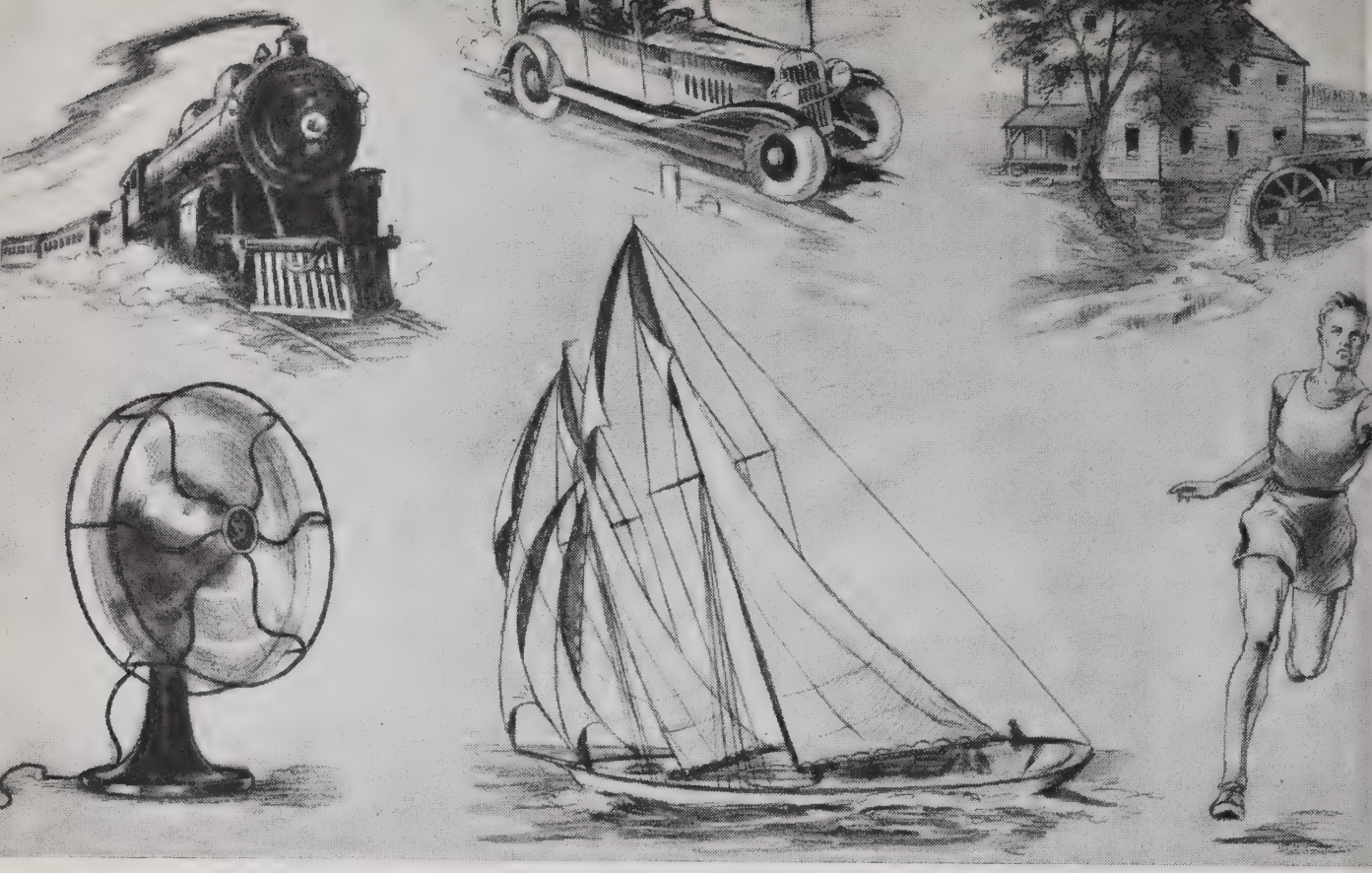


FIG. 248. Nothing moves without the use of some kind of *energy*. From what does the energy come that moves each of the objects in this picture?

Muscles need food in order to do their work. Now let us see why this is true.

When anything is moved, some force or *energy* is necessary to make it move. Your bicycle will move if you push down hard enough on the pedals. An automobile will move if gasoline is burned in the cylinders of the engine. The wheels of a steam engine will move when burning coal changes the water in a boiler to steam. Of course, bicycles, automobiles, and steam engines are not alive. You may think that because you are alive you do not need energy to make you move. But you do. The automobile engine and the steam engine get their energy from the fuel that is burned. You get your energy from the food you eat. Food is a fuel for you just as gasoline is fuel for an engine.

Before food can be used by the body, it must first be *digested.* In *digestion* the food you eat is made into a solution. The food you eat must pass through the walls of your stomach or your intestines (Figure 249) into the blood. It must also pass through the cell walls into the cells of your body. It must be dissolved before it can do this. But most of the food you eat has to be changed chemically before it will dissolve. Digestion changes your food and dissolves it so that it can pass through the walls of the intestines into the blood.

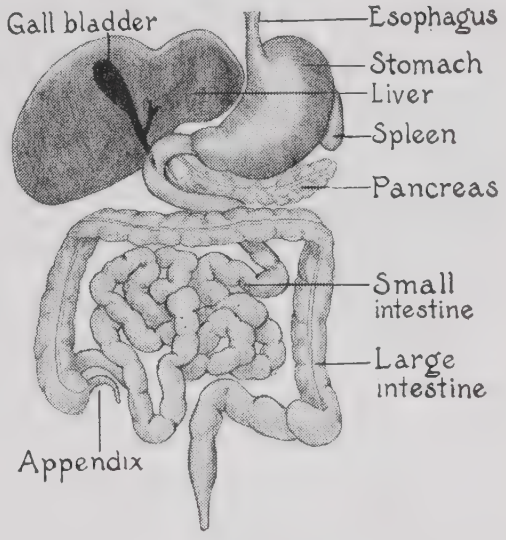


FIG. 249. These are the digestive organs of your body. Most of the digestion takes place in the small intestine, and most of the food passes into the blood from the small intestine.

You can understand digestion better if you remember what you learned on pages 91-101. You saw that sugar would dissolve in water and pass through filter paper. Starch would not dissolve in water; therefore it could not pass through filter paper.

Your food has to soak through the walls of the intestines and the stomach and into the cells of your body. It cannot do so unless it is dissolved. The water you drink will dissolve some of the different kinds of food you eat, but it will not dissolve all of them. Your *digestive system* provides juices that are needed to dissolve your foods so that your body can use them.

When a person says that there is something wrong with his digestion, he means that his digestive system is not

changing his food so that his body can use it. He may be eating the right kinds of food, but they are not doing his body any good. An experiment will help you to see how foods are changed in digestion.

Experiment 50. *How Is Food Digested?* Digest some white of egg in a test-tube. Make some artificial stomach juice by mixing together one-half gram of dry pepsin, one cubic centimeter of concentrated hydrochloric acid, and 500 cubic centimeters of water. Boil an egg until it is hard. Chop some of the white into very small pieces. The easiest way to do this is to push it through a piece of wire screen.

Put a level teaspoonful of the chopped white of egg into one test-tube and fill the tube with the artificial stomach juice. Put the same amount of chopped white of egg into another test-tube and fill this tube with very dilute hydrochloric acid. If possible, keep both tubes about as warm as your body (98.6° F.) for several hours or overnight. What happens to the white of egg in the stomach juice? To the white of egg in the acid?

When the dissolved food soaks through the lining of the digestive system, it passes into the blood. The blood carries the food all through the body to the cells. In every part of the body food and oxygen pass out of the blood and soak into the cells. In the cells the food combines with oxygen; in other words, it is oxidized (page 191). When this chemical change takes place, energy is released. This energy is used by the muscle cells to make the body move. Heat also is produced when food is oxidized. It is this heat that keeps the temperature of the body at about 98.6° F. Food, therefore, is the fuel of the body. It supplies the energy to move our muscles and the heat to keep us warm.

If you look at a picture of yourself when you were a

baby, you wonder how you could ever have been so small. How has your body been able to grow? What has taken place inside your body to make this change?

In Unit Eight you learned that the living protoplasm in cells can make new protoplasm. Cells grow larger, and new cells are made. This is what happens when you grow. But the cells must have materials to make new protoplasm. These materials are obtained from the food you eat. In the cells, meat, milk, potatoes, and other foods are made into bone, muscle, hair, and other parts of your body. Now you know another purpose for which the body uses food.

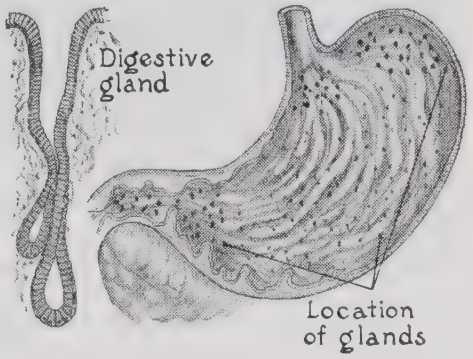


FIG. 250. In the lining of the stomach are tiny *glands* that manufacture digestive juices. The black dots in this picture show you about where the glands are.

Were you ever unfortunate enough to have a broken arm or leg? How was it repaired? When you break a part on your bicycle, you can replace it with a new part. But you cannot buy arms and legs like the ones you have. You call a doctor, and he brings the ends of the broken bones together; then places them in a cast. The cells in the bones then go to work. They use food to make new protoplasm and cells, and the bone finally grows together. Worn-out parts of the body are also repaired by the cells from materials they get in the food.

Our bodies also need food from which to manufacture compounds that are needed by the body. For example, we have certain chemicals in our stomach and intestines that digest the food. These chemicals are not found in the food we eat. The cells can, however, change some

of our foods into these chemicals. Other chemicals are needed to regulate how fast you grow, how fast your heart beats, how rapidly your food oxidizes, and how much your muscles contract. These chemicals are compounds that are made by your cells from the elements and compounds in the food you eat.

You will now understand that the cells of your body use food for four purposes: (1) They oxidize food to get the energy they use to do things and the heat to keep us warm. (2) They use food to build new body material as you grow—new protoplasm, new bone, new muscle, new nerve material. (3) They use food to repair the worn-out and injured parts of your body. (4) They get from food, or make from it, all the chemicals needed in the body. Anything that does one or more of these four things for the body is usually called a food.

Self-Testing Exercises

1. With your book closed, write down the four uses of food in the body.

2. How do the cells use oxygen? Why is this important?

3. Compare your body with a steam engine in the way your body gets its energy.

Problems to Solve

1. Where does oxidation take place in your body?

2. Does oxidation go on all the time or only part of the time? How do you know?

3. How does your body use energy while you are asleep?

4. What is the main use of food by a man digging a ditch?

5. How do your lungs help the cells do their work?

6. Where does the carbon dioxide that you breathe out come from?

7. Why do you breathe rapidly after running?

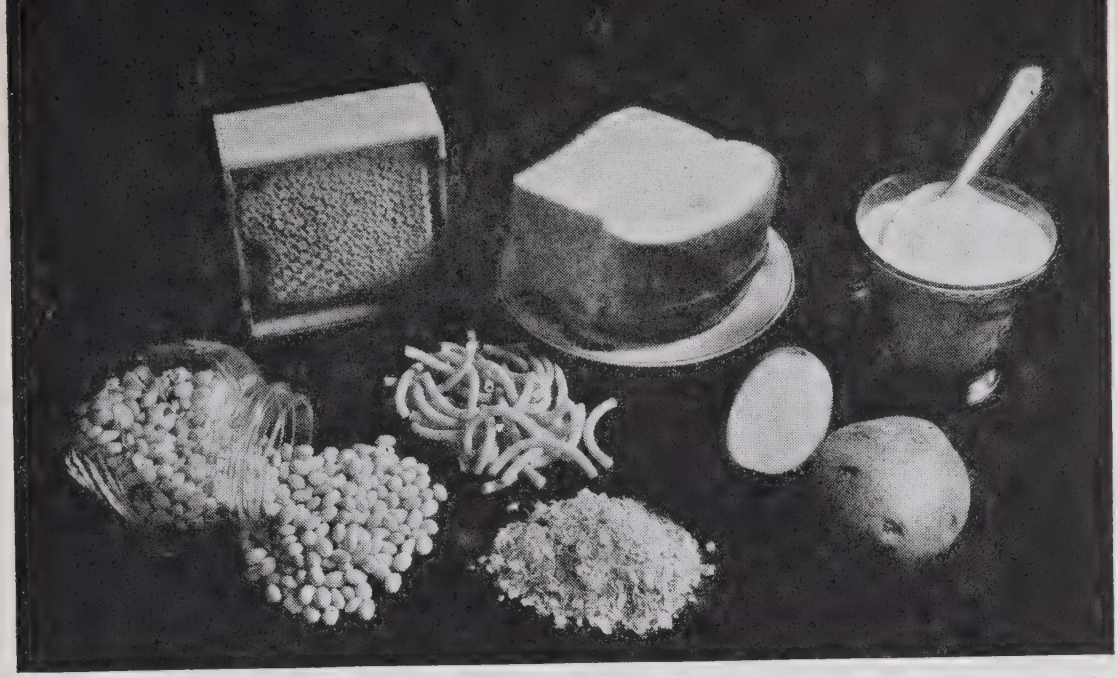


FIG. 251. Honey, bread, sugar, navy beans, macaroni, oatmeal, and potatoes contain much carbohydrates. These foods give the body warmth and energy.

Problem 2:

WHAT KINDS OF FOODS MEET THE DIFFERENT NEEDS OF THE BODY?

IN UNIT NINE you learned how plants make starch and sugar, and you learned that these food substances are called carbohydrates. Long ago chemists found four other kinds of substances that we all need in our food. These are *fats*, *proteins*, *minerals*, and *water*. Scientists then thought that if anyone got enough of each of these five kinds of substances, he would be healthy. Later, scientists discovered that we also need tiny amounts of other compounds, called *vitamins*. Why do our bodies need each of these kinds of food materials?

OF WHAT USE ARE CARBOHYDRATES AND FATS? Carbohydrates, as you know, are food materials containing three elements—carbon, hydrogen, and oxygen. Starch is a carbohydrate, and so is sugar. Table 8, on page 348, gives the percentage of carbohydrates in some common foods. Carbohydrates are fuel foods for the body. When they are digested, and carried to the cells by the blood, they unite with oxygen, and the energy

TABLE 8. Average Percentage Composition of Common American Food Products

Food Products	Water	Protein	Fat	Carbohydrates	Minerals	Fuel Value per Pound*
Beef, sirloin steak	54.0	16.5	16.1		.8	1100
Beef, round	60.7	19.0	12.8		1.0	890
Veal, leg	60.1	15.5	7.9		.9	625
Pork, loin	41.8	13.4	24.2		.8	1245
Ham, smoked	34.8	14.2	33.4		4.2	1635
Chicken, broilers	43.7	12.8	1.4		.7	305
Fish, perch	50.7	12.8	.7		.9	275
Eggs, hen	65.5	13.1	9.3		.9	635
Butter	11.0	1.0	85.0		3.0	3410
Milk, whole	87.0	3.3	4.0	5.0	.7	310
Cheese, cream	34.2	25.9	33.7	2.4	3.8	1885
Bread, white	35.3	9.2	1.3	53.1	1.1	1200
Crackers, soda	5.9	9.8	9.1	73.1	2.1	1875
Beans, string	83.0	2.1	.3	6.9	.7	170
Beans, dried	12.6	22.5	1.8	59.6	3.5	1520
Cabbage	77.7	1.4	.2	4.8	.9	115
Peas, canned	85.3	3.6	.2	9.8	1.1	235
Tomatoes	94.3	.9	.4	3.9	.5	100
Potatoes	62.6	1.8	.1	14.7	.8	295
Apples	63.3	.3	.3	10.8	.3	190
Bananas	48.9	.8	.4	14.3	.6	260
Oranges	63.4	.6	.1	8.5	.4	150
Dates, dried	13.8	1.9	2.5	70.6	1.2	1275
Raisins	13.1	2.3	3.0	68.5	3.1	1265
Peanuts	6.9	19.5	29.1	18.5	1.5	1775
Chocolate	5.9	12.9	48.7	30.3	2.2	2625

*The fuel value is given in *calories*. See page 363 for an explanation of calories.

that is stored in them is changed into heat energy and into the energy needed by the muscle cells to make the body move.

Since we cannot eat all of the time, it is necessary to store some of the food for future use. After a meal that contains much carbohydrates, the cells of the liver take much sugar from the blood and store it. This sugar is then given back to the blood to take to the cells when the cells need more food for energy. Our muscles always

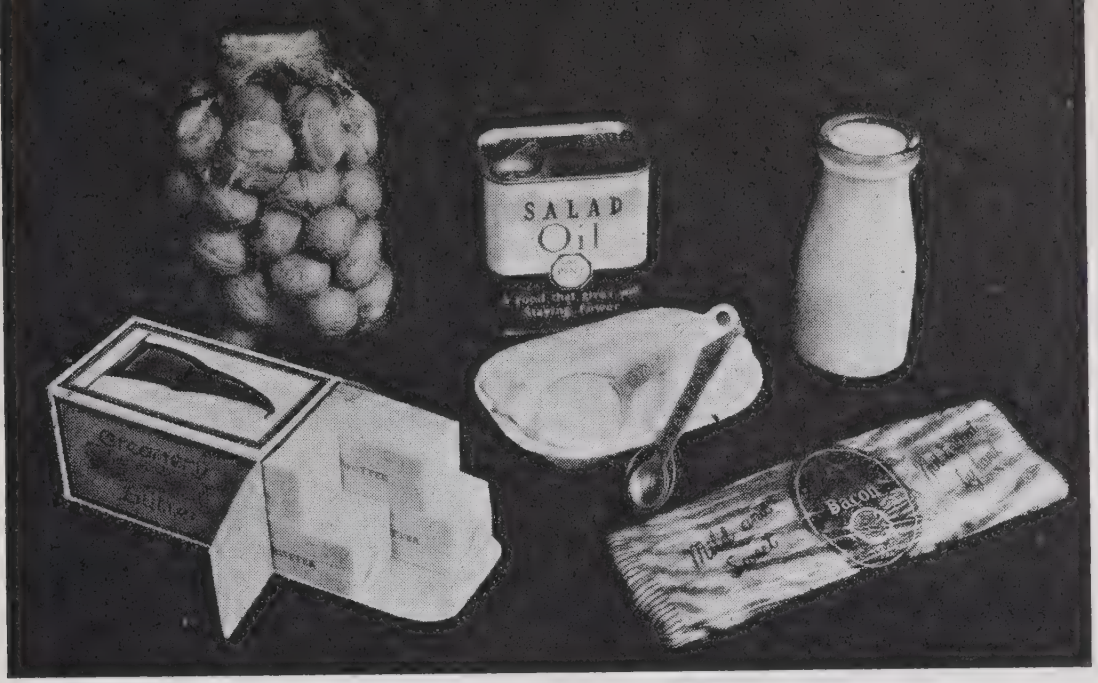


FIG. 252. These are some foods that contain much fat. Fats give us more energy than any other kind of food.

contain some stored carbohydrates, ready to release energy when we need to move quickly. Scientists think our cells can change carbohydrates to fat, too. Fat is also stored away to be used when necessary.

Fats are made of the same three elements that are in carbohydrates—carbon, hydrogen, and oxygen. But fats have less oxygen in them. More oxygen can unite with an ounce of fat than with an ounce of sugar; therefore, fats give out more energy than carbohydrates. When the body cells oxidize an ounce of fat, they get more than twice as much energy as when they oxidize an ounce of sugar. Fats are the most concentrated energy foods we can get.

As you know, all greasy and oily foods contain fats. A fat that is liquid at ordinary temperatures is called an oil. Cotton-seed oil, corn oil, and cod-liver oil are liquid fats that can be digested and used by the body. Butter and lard are foods that are almost pure fats. Fat meat, egg yolk, nuts, cream, and cheese, all contain large amounts of fat. (See Table 8.) Plants store most

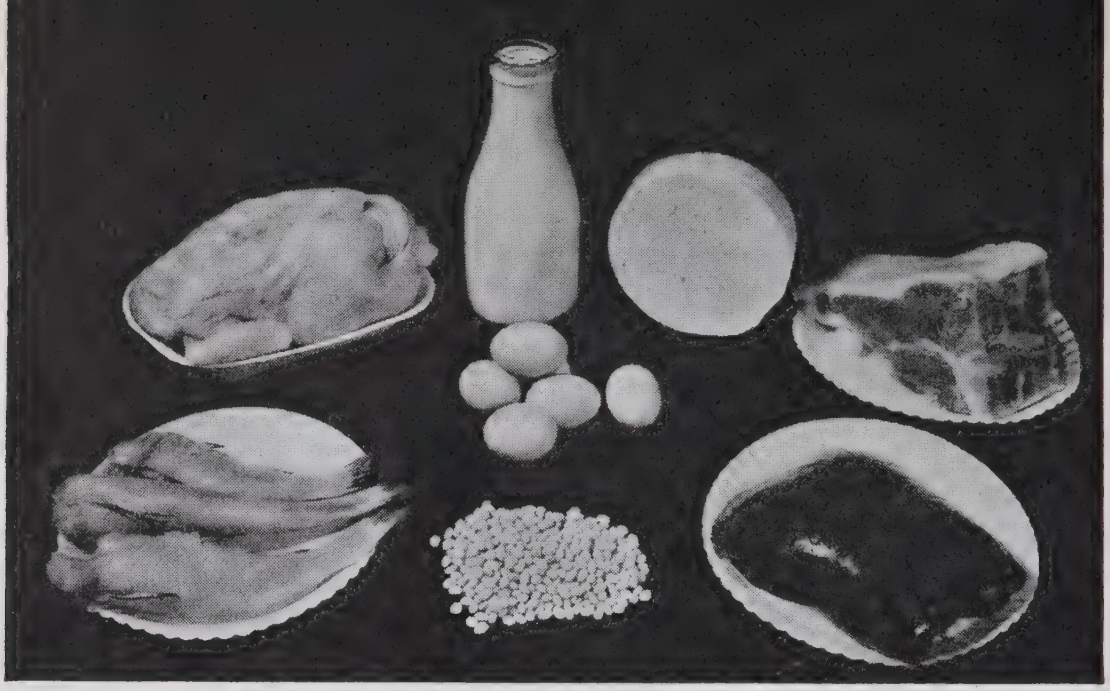


FIG. 253. Chicken, milk, cheese, steak, eggs, fish, navy beans, and liver are good protein foods. They provide "building materials" for the body.

of their extra food in the form of carbohydrates, but animals store much of theirs in the form of fats.

Carbohydrates and fats are both known as *energy foods*, or *fuel foods*. They are the foods that give us energy to move and heat energy for warmth. But we must eat something else besides starches, sugars, and fats. We must have foods to repair and build up the body, and foods to give the chemicals that are needed to regulate the body.

WHAT DO OUR CELLS USE PROTEINS FOR? Proteins are foods that always contain the element nitrogen in addition to the carbon, hydrogen, and oxygen found in carbohydrates and fats. Some proteins also contain sulphur and phosphorus. We get much of our proteins from such foods as eggs, lean meat, fish, cheese, and milk. Look at Table 8, page 348, and find a number of other foods that give us plenty of proteins.

Our bodies can oxidize proteins to get energy, but proteins have a much more important use. Protoplasm is made almost entirely of protein and water. Muscle

(lean meat), for example, is about one-sixth protein. Our cells cannot make proteins from carbohydrates and fats. Therefore, they must get proteins from food to make protoplasm for new cells and to repair old cells. Proteins are absolutely necessary to provide building materials for our bodies.

OF WHAT USE IS WATER IN THE BODY? Our bodies cannot oxidize water to get energy. Because water cannot be oxidized to get energy, some people think that it should not be called a food. Just the same, every one of us must have plenty of water in his body to keep alive. About two-thirds of your weight is water. About four-fifths of protoplasm is water. Water helps to carry on many of the chemical changes that are necessary to keep living things alive.

Water is also important in our bodies because it helps to dissolve materials and helps to carry them to different parts. Much water is poured into our digestive organs to help dissolve our food. The blood that carries dissolved materials from one part of the body to another is eighty-one per cent water. Water that leaves the body through the sweat glands in the skin and through the kidneys carries much waste material out of the body. Water helps to keep our bodies cool by evaporating when it is poured on our skin by the sweat glands. Everyone should see that his body receives plenty of water.

Almost all our foods contain some water. Juicy fruits and vegetables, such as melons, apples, and tomatoes, are mostly water. (See Table 8, page 348.) However, we must get most of the water that our bodies need in liquid form, either as pure water or in soups, milk, and other beverages.

FIG. 254. Milk, fruits, and vegetables are our most important mineral foods.

OF WHAT USES ARE THE MINERALS IN OUR FOODS? When food is burned as completely as it can be, minerals are left. You probably call these minerals ashes, and that is a good name, because chemists call them *ash* when they analyze food.

From the food we eat and the water we drink we must get minerals that will give us all the elements our cells need to build our bodies and to make the chemicals that our bodies need. (Table 8, page 348, gives the percentage of minerals in common foods.) As you learned in Unit Eight, we need calcium and phosphorus in rather large amounts to make bones and teeth. New red blood cells cannot grow without iron and copper. A certain important gland called the *thyroid gland* cannot make its chemical without iodine. Lack of the right amount of iodine often causes a disease called *goiter*, in which the thyroid gland becomes much enlarged.

Sodium, potassium, magnesium, chlorine, manganese, fluorine, and probably other elements are all needed to keep the body working in a healthy manner.

Scientists have learned by analysis and by feeding experiments that most people get all the mineral elements they need except four: calcium, phosphorus, iron, and iodine. We should choose foods with care to make sure of getting enough of these elements. Milk, cheese, meats, and spinach furnish large amounts of calcium, phosphorus, and iron.

Sea foods are especially rich in iodine. In the central part of the United States people cannot get sea foods easily. Therefore some scientists think that these people should use salt that contains a very small amount of a compound called sodium iodide (NaI). As you can tell by the name and the formula, this compound contains iodine. Salt that is mixed with a little sodium iodide is labeled "iodized salt."

FIG. 255. If you live on a farm where there are cows, pigs, and other animals, you know how food affects the growth of animals. These two puppies are the same age. They were fed on the same food, except that the little one never had any milk to drink.

WHY ARE VITAMINS IMPORTANT IN OUR FOODS? The discovery of vitamins is one of the thrilling stories of modern science. For thousands of years mysterious diseases have killed human beings in every part of the world. About the year 1875 Louis Pasteur, Robert Koch, and other great scientists were able to prove that some of these diseases were caused by *germs*. Germs are one-celled plants and animals that live as parasites in our bodies. Later in your study of science

you will learn more about the diseases that are caused by them. But there were still a number of important diseases whose causes could not be discovered. Since 1909 scientists have learned that some of these strange diseases are caused by peoples' failure to eat foods that have vitamins in them.

In 1519 the famous Magellan set out to sail around the world. During the journey across the Pacific Ocean, his sailors' mouths became sore, their gums bled, their joints swelled up, and the men screamed with pain. These sailors had *scurvy*. Scurvy was common on ships that went on long journeys. Once a Spanish war-ship was found drifting on the ocean; every sailor had died of scurvy! When Vasco da Gama sailed around the Cape of Good Hope, 100 of his 160 sailors died of this disease. This was in the year 1498.

Another mysterious disease afflicted people all through China and Japan, and in many other parts of the world. People would notice that their legs were beginning to feel numb. Later they suffered pain in the calves of their legs. They would get worse and worse until they became paralyzed and died. These people had *beri-beri*. In 1879 nearly 2000 men in the Japanese navy had beri-beri. This was four sailors in every ten. Beri-beri was rather common in Labrador and Newfoundland. In 1916 the British soldiers fighting in southeastern Asia got beri-beri. Even as late as 1930 a Danish whaling ship on a trip to the southern seas had fifty-one cases of beri-beri.

Throughout the world, especially in places where people do not get much strong sunlight, many children have soft bones. These bones become crooked because they cannot support the weight put on them. This

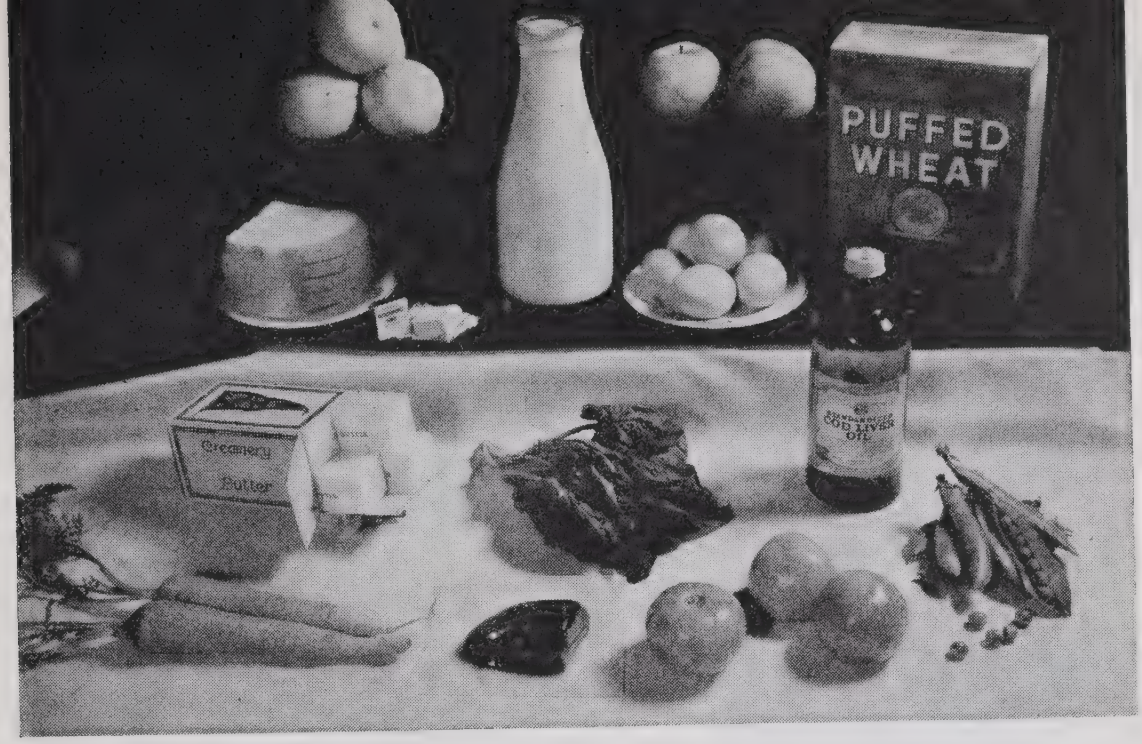


FIG. 256. Some of the foods that are rich in vitamins are shown in this picture.

is caused by a disease called *rickets*. In 1920 it was found that one-tenth of all badly crippled children in English schools were crippled because of rickets. In the years 1925 to 1926, ninety-six per cent of the babies in one city in the United States showed signs of rickets. Thus, all over the world millions of people are handicapped because they have had more or less severe cases of rickets at some time in their lives.

Another mysterious disease, called *pellagra*, has long been common in some parts of our country. In this disease there is a peculiar breaking-out of the hands, feet, and face. Those who have it become nervous and fearful. They cannot sleep at night. In 1917 there were 170,000 cases of pellagra in the United States. Seven thousand people in the United States died of pellagra in 1930.

Gradually scientists learned that food had something to do with these four terrible diseases. Magellan's sailors got well when they reached the Philippine Islands, where there was fresh food to eat. Doctors of the British navy

FIG. 257. This pig had plenty of the right kind of food to make its bones grow, but it did not get enough of the right kind of vitamin. Therefore the pig developed such a case of rickets that, as shown at the left, it could not stand on its front legs. But daily doses of cod-liver oil cured the pig.

learned that the sailors did not get scurvy if they had orange juice or lemon juice to drink.

To cure beri-beri, a doctor in the Japanese navy tried an experiment with better food for the men on one ship. The experiment was so successful that his plan was used for all the men in the Japanese navy. Eight years later not a single case of beri-beri was reported in the whole navy. In 1910 a ship loaded with whole-wheat flour was blown ashore in Labrador. To lighten the ship, much of the flour was unloaded. This flour was used by people in that region, and for a whole year not a single case of beri-beri was found.

Another strange fact about disease and food was learned when people found out that oil from the livers of codfish prevented rickets. In regions where the people ate much codfish, there was no rickets. Eskimos never had rickets; most of their food was fat and oil from fish. Another strange fact was discovered about rickets. During the World War a doctor in Germany found that children who had rickets got well when they were exposed to the light from "sun lamps." In the United States Dr. Steenbock, at the University of Wisconsin, discovered that rats would not get rickets if their food was put under a "sun lamp" for ten minutes.

About 1915 a Dr. Goldberg, after long, careful study, proved that people who ate fresh meat and drank milk did not get pellagra. Later he learned that yeast would cure the disease.

All these facts that scientists were learning made them sure that food did something more than give us energy and help us to grow. They became sure that there was some mysterious substance in food that helped keep us from getting diseases. So the scientists began to experiment. They experimented by giving different foods to such animals as rats and guinea pigs.

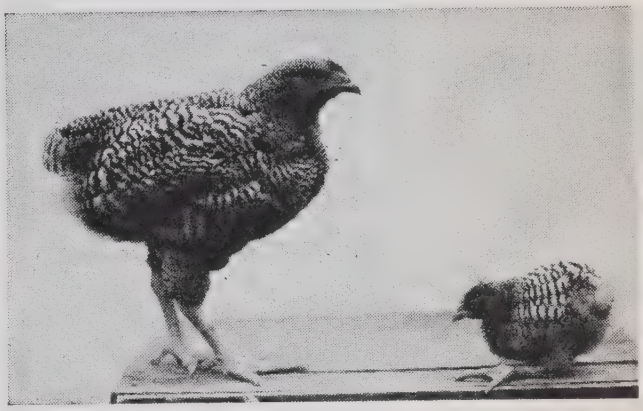


FIG. 258. Lack of vitamins in the food of the smaller chicken made the difference in the sizes of these two chickens. They were both hatched at the same time.

It did not take the scientists long to find out that these animals could not live long on a diet of pure carbohydrates, fats, proteins, minerals, and water. In 1912 a scientist found that only one-half teaspoonful of milk each day, along with the other foods, would keep one rat healthy. Rats that did not have the milk were not strong and healthy. Then the scientists found that a little yeast powder added to food seemed to do the same thing as milk. What could be in milk and yeast that had such magic effects?

All over the world scientists began to work on this problem. What one scientist learned, he told to other scientists. Finally scientists were able to prove that there are some strange chemical substances in certain foods that we must all have to keep well. If our bodies do not get these substances, we develop scurvy, beri-

beri, rickets, or pellagra, depending on what substance is missing. But we need very small amounts of these chemicals. To prevent rickets, one needs each day a bit of a certain chemical compound only as big as the period at the end of this sentence.

These tremendously important chemicals that keep us well are called vitamins. Because they did not know what these chemicals were, scientists named them by letters of the alphabet—vitamins A, B, C, D, E, and G. Chemists have now found exactly what chemical compounds some of the vitamins are. They have actually made some of them. They are still studying and experimenting to learn about the others.

Most of us do not need to know just what kind of food contains each kind of vitamin. We get plenty of vitamins in the foods we eat. A good American diet, with plenty of meat, whole-grain bread and cereals, milk and butter, and fresh fruits and vegetables (expecially raw tomatoes or lemons or oranges), contains all the vitamins most of us need.

There is just one possible danger for most people. Vitamin D, which prevents rickets and helps make good, sound teeth, is made in some foods and in our own bodies by certain invisible rays from the sun. These rays are called *ultra-violet* rays. In winter we wear heavy clothes and stay indoors a great deal. Also, in most parts of our country the sunlight is partly shut off by clouds and by smoke from chimneys much of the time in winter. Thus our bodies may not get enough of this vitamin.

In winter growing children should have cod-liver oil, halibut-liver oil, or some other material that contains large amounts of vitamin D. This lack can also be

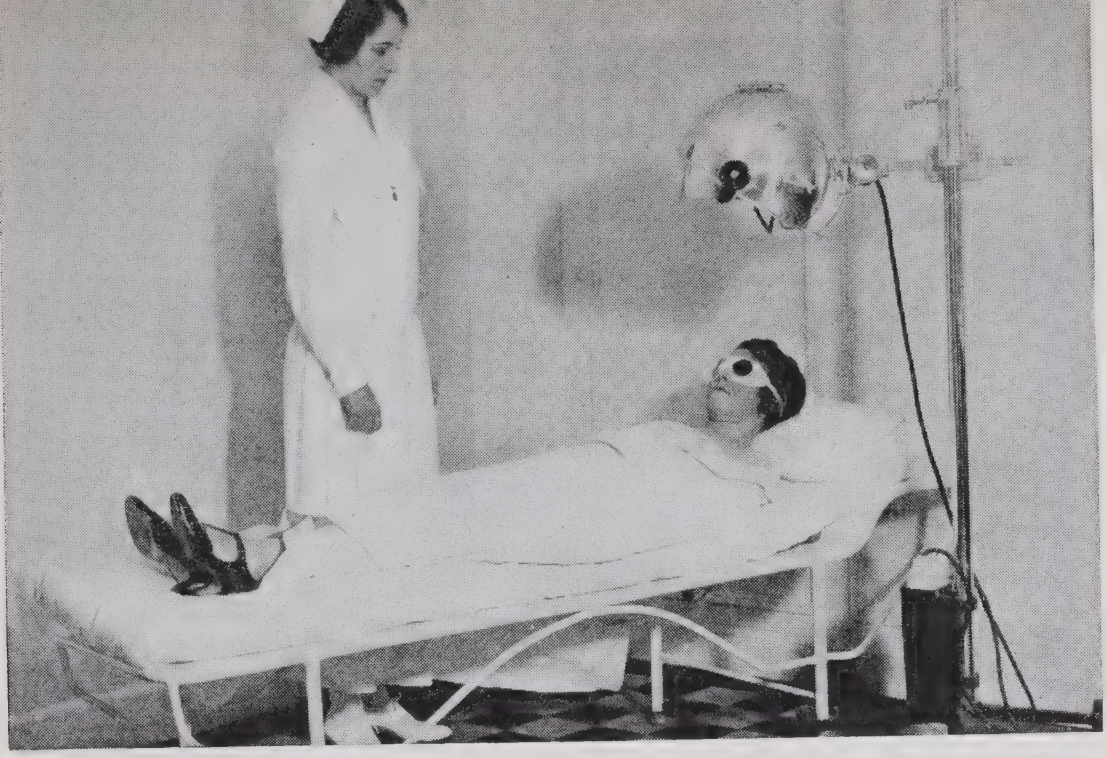


FIG. 259. Sun lamps like this one have helped cure many people of illness.

made up by exposing our bodies to the light of a good "sun lamp." However, there are dangers in taking too much vitamin D and too much light from a sun lamp. You should, therefore, follow the advice of your doctor, especially in using a sun lamp.

Eating more vitamins than you need will not improve your health. Most people do not need to buy medicines and specially prepared foods that are advertised as containing a great deal of vitamins.

Self-Testing Exercises

1. Make a table like the one below, and fill it in.

CHARACTERISTICS AND USES OF THE DIFFERENT CLASSES OF FOODS

Class of Food	Elements in This Food	Common Sources of This Food	Use in Body
Carbohydrates, etc.			

2. From the record you made for Introductory Exercise 1, make a list of the foods of which you eat the most. After

each food in your list write letters or words to show which kind, or kinds, of food materials are found in each food in large amounts. Use Table 8, page 348, to help you.

3. Why is cod-liver oil or some similar substance recommended for almost all babies in the northern states during the winter? Why do they not need as much of it in the summer?

Problem to Solve

On page 161 you learned how to test foods for starch. If you did Problem 2 on page 329, you know how to test for sugar. You can also test them for fats, proteins, minerals, and water. Try these tests.

a) Fats. Mash a small piece of the food on a sheet of glazed (slick) paper and warm it over a flame. Look for a "grease" spot. This can be most easily seen by holding it up to the light. The light will pass through the spot better than through the rest of the paper. The grease-spot test shows only those foods that contain a rather large amount of fat.

b) Proteins. Put a small sample of the food in a test-tube. Add a few drops of concentrated nitric acid. Heat the tube gently. If the food contains protein, it will turn yellow. Pour off any extra nitric acid and put in an inch or two of ammonium hydroxide or household ammonia. The ammonia will make the yellow color darker or change it to orange.

c) Minerals. Put a small sample of the food in a shallow iron pan, or in an iron spoon, or on a piece of sheet iron. Heat the under side of the iron as hot as you can and keep it hot until all the food has burned and only a white or gray material is left. This is the mineral matter, or ash, in the food.

d) Water. Plan your own experiments to find whether foods contain water. If you heat them, be sure not to use heat enough to decompose them. By weighing your samples, you can find whether foods contain much or little water.

FIG. 260. From what you learned in Problem 2, see if you can tell whether or not this girl is eating a well-balanced breakfast.

Problem 3:

HOW CAN WE SELECT OUR FOODS WISELY?

IN SPITE of all we know about food, we often do not choose our foods wisely. We may be too lazy! Or we may read so much about foods that we get confused and say, "What's the use? I can never select just the right foods, anyhow." But it is really not very hard to know what to eat. A few simple rules tell us how to choose our food. Since you have studied Problem 2, you will understand the reasons for each rule.

In some homes boys and girls, as well as fathers and mothers, may find it hard to follow the rules. But to keep healthy they should do their best to follow them. By careful planning, many families can improve their selection of food without spending any more money.

You are now going to learn some of the things that scientists have found out about how much food you need. Then at the end of the problem you will find the rules for choosing food.

HOW CAN WE KNOW HOW MUCH FOOD TO EAT? Is your appetite a safe guide in deciding how much food to eat? The answer depends on you and your appetite. Some boys and girls have appetites that are healthy and well trained; such appetities may be followed safely. Some people have never had the chance to eat the most healthful selection of foods. Others have appetities that have been spoiled; such appetites are a poor guide in eating enough to keep strong and growing. Some appetites are always calling for sweet foods and candy; their owners do not eat enough of the better kinds of food.

Some people, especially older persons, so greatly enjoy eating that they become too fat. Overeating puts a strain on the digestive system and on the kidneys, because these organs have to get rid of the wastes from foods that are not needed. When people eat so much that they become too heavy, there is an extra strain on the heart and the other parts of the circulatory system. We should be intelligent about how much food we need, in order to guide and control our appetites.

The amount of food a person needs depends upon a number of things. Growing boys and girls need more building material in proportion to their size than an older person needs. A large person needs more food than a small person. A person who is doing hard physical work or exercising vigorously needs more food than a person who gets little exercise. We need more food when we are out in the cold than when we are in a warm place. And finally, people are different in the amounts of food they need. Foods that are good for most of us may cause indigestion in a few people.

To tell just how much food people should eat, scientists

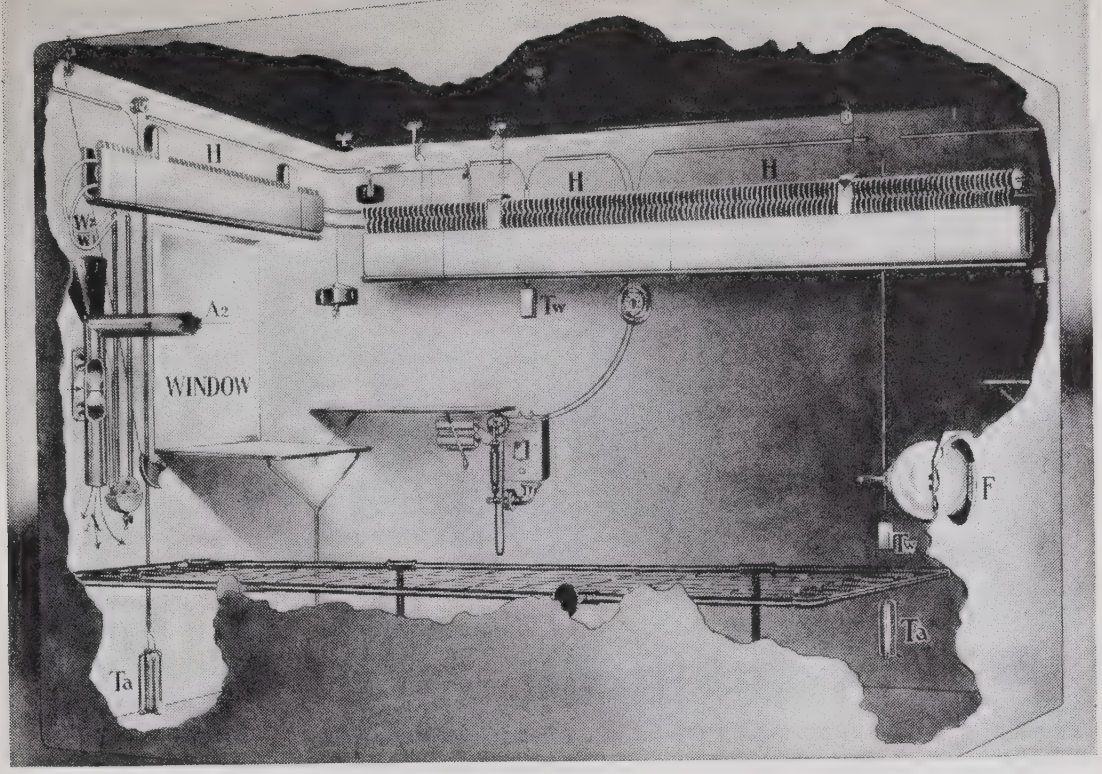


FIG. 261. This is a picture of one kind of apparatus used to measure the amount of energy a person's food gives him. It is really a room full of delicate measuring instruments. You can easily believe that scientists had to solve many problems before they knew how to make this apparatus. (Carnegie Nutrition Laboratory, Washington)

have done two things. First, they have learned how much energy a gram of each kind of food contains. They measure the energy, or *fuel value*, of a food by finding how much heat it gives out when it is completely oxidized. This energy is measured in *calories*. One calorie is the amount of heat needed to raise the temperature of a kilogram (1000 grams) of water one degree centigrade.

Perhaps you will understand this better if we say that one calorie of heat will raise the temperature of one pound of water about four degrees Fahrenheit. One gram of pure carbohydrate, when it is oxidized, gives out about 4.1 calories of heat. One gram of pure fat gives out 9.3 calories, and one gram of pure protein gives out, on the average, 4.1 calories. Table 9, on the next page, shows the amounts of different kinds of food required to produce 100 calories of energy in the body.

TABLE 9. Approximate Amount of Food Required to Supply 100 Calories of Heat*

Name of Food	Portion Supplying 100 Calories of Heat (Approximate)	Weight of Food (Ounces)
(A) COOKED MEATS		
Beef, round, boiled	Small serving	1.6
Beef, fifth rib, roasted	Small serving	1.2
Lamb, leg, roasted	Ordinary serving	1.8
Pork, ham, boiled	Ordinary serving	1.1
Veal, leg, boiled	Large serving	2.4
Chicken	Large serving	3.2
Pork, loin	Very small serving	.97
(B) VEGETABLES		
Asparagus, cooked	Very large serving	7.19
Beans, baked	Small side dish	2.66
Beans, string	Five servings	16.66
Cabbage, fresh	Three servings	11.0
Corn, sweet	One side dish	3.5
Onions, cooked	Two large servings	8.4
Peas, canned	Two servings	6.3
Potatoes, baked	One good-sized serving	3.05
Tomatoes, fresh	Four average servings	15.0
(C) FRUITS		
Apples, raw	Two apples	7.3
Bananas	One large	3.5
Cantaloupe	Half ordinary serving	8.6
Grapefruit	One-half	7.57
Oranges	One very large	9.4
Peaches	Three ordinary	10.0
Pears	One large	5.40
Strawberries	Two servings	9.10
(D) DAIRY PRODUCTS		
Butter	One pat	.44
Buttermilk	One and one-half glasses	9.7
Cheese, full cream	One and one-half cu. in.	.82
Cream	One-quarter ordinary glass	1.7
Milk, whole	Small glass	4.9
Hen eggs, boiled	One large egg	2.1
(E) CAKES, DESSERTS, SWEETS		
Cake, chocolate layer	One-half ordinary piece	.98
Custard, milk	Ordinary cup	4.29
Doughnuts	Half a doughnut	.8
Pie, apple	One-third piece	1.3
Pudding, brown betty	Half ordinary serving	2.0
Sugar, granulated	Three teaspoons or one and one-half lumps	.86

TABLE 9. CONTINUED

(F) NUTS		
Almonds	Eight to fifteen	.53
Brazil nuts	Three ordinary size	.49
Filberts	Ten nuts	.48
Peanuts	Thirteen, double	.62
Walnuts	About six	.48
(G) CEREALS		
Bread, corn	Small square	1.3
Bread, white	Ordinary thick slice	1.3
Corn flakes	Ordinary cereal dish	.97
Crackers, graham	Two	.82
Oatmeal, boiled	One and one-half servings	5.6
Rice, boiled	Ordinary cereal dish	3.1
Shredded wheat	One biscuit	.94

*Data compiled by Dr. Irving Fisher, Yale University.

The second thing scientists have done is to study very carefully how much energy different people use in a day. A very complicated apparatus (Figure 261) measures the oxygen a person uses, the carbon dioxide he gives out, the heat he makes, and the amount of work he does. When the scientists know these things, they can figure out how much energy a person's food should give him.

TABLE 10. CALORIES REQUIRED BY DIFFERENT INDIVIDUALS

Individual	Occupation	Calories Required per Day
Man	Moderately active muscular work	3500
Man	Light muscular work	3150
Boy of 15		3150
Man	Sedentary work	2800
Woman	Moderately active work	2800
Boy from 13 to 14		2800
Girl from 15 to 16		2800
Woman	Light work	2450
Boy 12		2450
Girl 13 to 14		2450
Boy 10 to 11		1800
Girl 10 to 12		1800

Experts who plan diets for large numbers of people consult a table like Table 10 to learn how much energy each person needs. Then they select the proper amounts of food by the use of tables like Table 9. In this way they can work out a good diet for any group of people.

However, you probably do not need to spend much time counting up the number of calories of food energy you need. Each one of us, if he is not sick, should eat enough to keep himself feeling strong and energetic throughout the day. Young people should, of course, eat enough to gain weight gradually as they grow. Look at Table 11 and compare your weight with the average for your age and height.

The averages given in Table 11 may not quite fit you. Persons who are broad and heavy-bodied will weigh more than the average for their height. Those who are slender will weigh less. But if your weight is quite far below the average, you probably should eat larger amounts of nourishing foods. On the other hand, if you are much heavier than the average for your age and height, you may need to eat less. Eat protein foods to give your body building material, but avoid overeating of foods that are rich in carbohydrates and fats.

There is one bit of advice that some of you may need. It is this: Do not try to reduce just to be stylish. Young people, especially girls, are naturally plump if they are healthy. And all through your life avoid trying the lazy way to reduce; the lazy way is to take advertised drugs. These remedies are either worthless or dangerous. If you really need to reduce and cannot do it by self-control in eating and by taking plenty of exercise, talk to your doctor and do what he says.

TABLE 11. HEIGHT-WEIGHT-AGE TABLE*

AGE	11 YR.		12 YR.		13 YR.		14 YR.		15 YR.		16 YR.	
Height, Inches	B†	G†	B	G	B	G	B	G	B	G	B	G
46	49	49		49								
47	51	51	51	52								
48	54	53	54	54								
49	55	56	56	58		58		58				
50	58	61	58	62	59	63	59	64	60			
51	61	63	61	65	62	66	62	69	63			
52	64	65	64	67	64	69	65	71	66			
53	67	68	68	69	68	71	69	73	70			
54	70	71	71	71	71	73	72	75	73			
55	73	74	74	75	74	77	74	78	76	79	77	
56	77	78	77	79	78	81	78	83	80	86	81	89
57	81	82	81	82	82	84	83	88	83	92	84	96
58	84	86	85	86	85	88	86	93	87	96	88	101
59	88	90	89	90	89	92	90	96	90	100	90	103
60	92	95	92	95	93	97	94	101	95	105	96	108
61	95	99	96	100	97	101	99	105	100	108	103	112
62	100	104	101	105	102	106	103	109	104	113	107	115
63	105	108	106	110	107	110	108	112	110	116	113	117
64	108	112	109	114	111	115	113	117	115	119	117	120
65	112	116	114	118	117	120	118	121	120	122	122	123
66	115		117	122	119	124	122	124	125	125	128	128
67				126	124	128	128	130	130	131	134	133
68				130		131	134	133	134	135	137	136
69						134	137	135	139	137	143	138
70						136	143	136	144	138	145	140
71						138	148	138	150	140	151	142
72									153		155	
73									157		160	
74									160		164	

* After tables by Bird T. Baldwin and Thomas D. Wood. Age is taken at the nearest birthday; weight is taken at the nearest pound.

† B represents boys. † G, girls.

In this table the following allowances for clothing, except shoes and sweaters, have been included—BOYS: 35-63 pounds, 3.5 per cent of the net weight; 64 pounds or more, 4 per cent of the net weight. GIRLS: 35-63 pounds, 3 per cent of the net weight; 64-82 pounds, 2.5 per cent of the net weight; 83 pounds or more, 2 per cent of the net weight.

HOW CAN WE SELECT THE RIGHT KINDS OF FOOD TO EAT?

You have learned how important it is to eat different kinds of food so that your body will get everything it needs. At each meal we should eat some food that has a large amount of protein. The animal proteins,

FIG. 262. This is a good breakfast for a growing boy or girl—oatmeal, toast and butter, cocoa, milk, and baked apple.

such as meat, eggs, milk, and cheese, have the kinds of proteins that our bodies need most. However, eating too much protein does little good; it only makes our bodies use protein for energy and overworks the kidneys to get rid of extra wastes.

With every meal we should eat some carbohydrates and fats to give us energy. Starch and sweet foods have large amounts of carbohydrates. Candy is much better for us if it is eaten as part of the dessert than if it is eaten between meals. Butter is one of the most healthful fats.

We should eat plenty of fresh fruits and vegetables, both raw and cooked, and a reasonable amount of whole-wheat products or whole-grain cereals. This group of foods fills three needs in the body. They are rich in vitamins that we need to keep healthy. They contain minerals we need to grow and to keep the body working well. And the fibers and indigestible parts of fruits and vegetables fill up the large intestine and stimulate it to empty itself regularly.

Every person should also have plenty of milk. Milk contains valuable carbohydrates, fats, and proteins. It also has an unusual amount of the bone-building mineral elements, calcium and phosphorus. A quart of milk contains more calcium than a growing person needs in a day and more than half enough phosphorus. Milk is also

FIG. 263. Cream of tomato soup, milk, white bread and butter, prunes, and cookies at noon will provide plenty of energy and building material for the work and play of the afternoon.

FIG. 264. An evening meal of lamb stew, potato, spinach, whole-wheat bread, butter, milk, and rice pudding completes a day of good nourishing food to take care of all the body's needs.

rich in several of the vitamins. Most of us can digest it easily. It is no wonder, then, that milk is considered one of our most valuable foods.

The rules on the next page will help you remember what scientists have learned about the kinds of food we should eat. Most of you will get the right kinds of food to keep healthy if you use these rules. If you find that you do not have good digestion or do not keep healthy and strong when you follow these rules, make careful changes or talk to your family doctor and follow his advice.

1. *Eat regularly three meals a day.* If you are very active, you may find that a light lunch of easily digested food in the middle of the morning and again in the middle of the afternoon will make you feel better. However, such lunches should not cause you to eat more than you really need, and they should not regularly be of candy.

2. *Eat a serving of food rich in protein twice a day.* One serving of meat (excluding bacon) is enough for persons who are not doing hard labor.

3. *Eat at least two generous servings of vegetables daily, one of them a green, leafy vegetable.* You have already learned the value of these foods.

4. *Eat two servings of fruit each day, one of them raw.* Oranges, lemons, grapefruit, and tomatoes should be eaten for a valuable vitamin they contain. This vitamin is destroyed by cooking food.

5. *Avoid overeating of sweets.* Candy and other very sweet foods spoil one's appetite for other foods. They may also overwork certain glands of the body, thus leading to a serious disease called diabetes.

6. *Eat a whole-grain cereal or two slices of whole-wheat bread each day.*

7. *If you are young, drink at least a quart of milk a day. After you have grown up, use a pint a day.*

8. *Drink four to six glasses of water each day.*

Self-Testing Exercises

1. Copy the eight rules given above. Leave enough room below each one to write a paragraph. Close your book and write the reason or reasons for each of the eight rules. If you cannot do so, study this unit until you can.

2. After having studied your own eating for a week, as directed in Introductory Exercise 1, tell which of the eight

rules you follow and which you do not follow. If there are some of the rules you do not follow, give your reasons for not following them.

Problems to Solve

1. Criticize the set of meals shown below on the basis of the eight rules.

Breakfast	Dinner	Supper
Oatmeal with cream	Corned beef	Corned beef
Fried eggs	Boiled dried beans	Fried potatoes
Fried ham with gravy	Boiled potatoes	White bread
Hot biscuits	White bread	Butter
Butter	Butter	Apple-sauce
Jam	Jelly	Cake
Coffee	Apple pie	Coffee
	Coffee	

2. On his expeditions to the South Pole, Admiral Byrd had to provide food for a large group of active men for several months in a region where no plants grow. What difficulties do you see in providing food to keep the men in good condition? How could the difficulties be solved? If you know the types of food that Admiral Byrd actually took, tell about them. Perhaps you can find out about them by reading.

3. During the World War some submarines and other ships were forced to cease their activities because of scurvy among their crews. Give the reasons why this disease may have broken out.

4. From Table 10 find how many calories of energy you need in a day. Then from Table 9 make up a day's menu that is well selected and gives about the right amount of energy.

5. List some days on which you need more than the usual amount of food and some days when you need less. Give the reasons in each case.

LOOKING BACK AT UNIT TEN—SUMMARY EXERCISES

1. Write down all the principles, or big ideas, of science that you have learned from this unit. Write them as complete sentences.

2. Show that you know the meaning of each of these words:

vitamin	*calorie*	*fuel value*	*fuel foods*
protein	*digestion*	*thyroid gland*	*rickets*

ADDITIONAL EXERCISES

1. The temperature of a reptile's body is very nearly the same temperature as that of its surroundings. The body temperature of birds is higher than that of man. Would a lizard (reptile) or a bird of the same weight need the larger amount of food? Why?

2. Compare the materials we put into an automobile or a locomotive to make it go with the materials we must put into our bodies. Remember to consider all four requirements of the body, as given on page 346.

3. How may harmful germs get into food? Make as long a list of ways as you can.

4. How could you find out by an experiment about what per cent of an apple is water?

5. Visit a grocery store and see how foods are protected from handling, from insects, and from dirt.

6. Why do we need to eat more food in the winter than in the summer?

7. Why does a person get much hotter when he exercises?

8. Find out how energy is stored in food.

9. Use Tables 9 and 10 to make up a satisfactory menu for a man who is quite active all day and another menu for a man who sits at a desk all day.

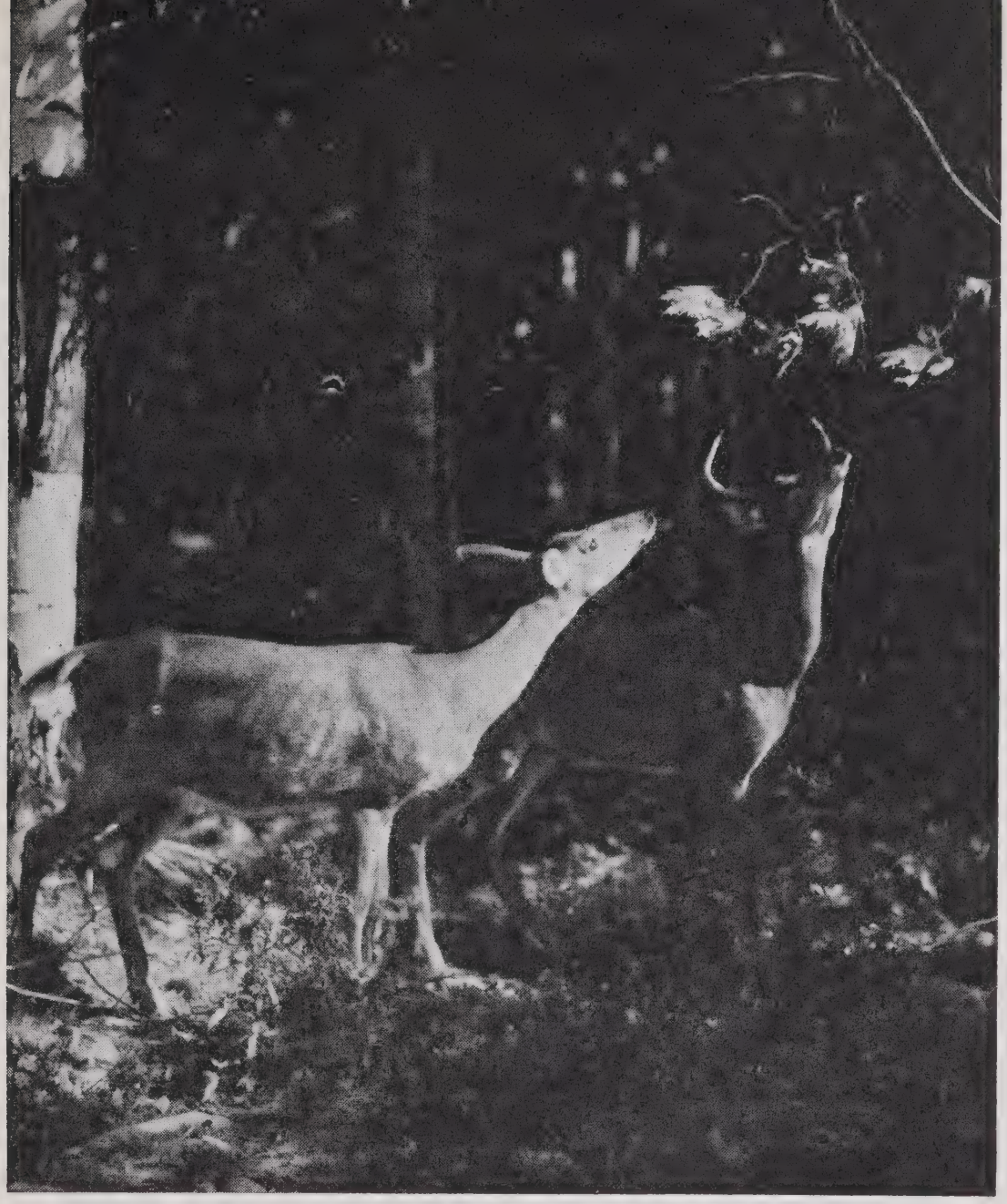


Fig. 265. The world is a great community of living things that need each other in countless ways. Animals must have plants, and animals also help plants. Animals help and harm each other, and plants help and harm each other. You can see how these deer are harming the plants and how the plants are helping the deer. In this unit you will learn of many other interesting ways in which living things help and hinder each other.

UNIT ELEVEN

UNIT 11

HOW DO PLANTS AND ANIMALS LIVE TOGETHER?

INTRODUCTORY EXERCISES

1. Make a list of things we get from plants. Divide your list under these headings: *food*, *clothing*, *shelter*, *medicine*, *pleasure*.

2. Under the same headings you used in the exercise above, list things we get from animals.

3. You live in a community. Tell what the word "community" means.

4. In what ways do plants compete with other plants?

5. In what ways do animals compete with other animals?

6. Why does the number of any kind of animal remain about the same year after year; that is, why are there always about the same number of robins, crows, or rabbits?

7. A sudden storm swept over a shallow lake, tearing loose from the bottom and killing most of the green plants growing in the lake. In a few days hundreds of fish in the lake were found dead, and others were at the top, gasping for air. Can you guess why?

8. Are bacteria ever useful to plants and animals? Explain.

9. Some animals, such as ants and beavers, live in large families or colonies. Could one of these animals live as well by himself as he does with the colony? Give reasons to support your answer.

10. A single oyster produces an average of 80,000,000 eggs in one season. Why are oysters not more abundant on seacoasts?

FIG. 266. In a dry desert region like this there are almost no living things. Plants cannot grow because of lack of water, and animals cannot live because there are no plants.

LOOKING AHEAD TO UNIT ELEVEN

IF YOU WERE shipwrecked on an island where no living thing existed, could you keep alive? Of course you might catch fish and other animals from the sea. But suppose that there were no living creatures in the sea. Alone on the island you would soon die. Someone has said that "no one lives unto himself." This means that no living thing could remain alive if it were not for other living things. Every living thing needs other living things in some way.

You, of course, live in some kind of community. It may be a farming community, a small town, or a large city. In your community there are many people; each of these people is helping the life of the community in some way and also the life of other communities. All over the world there are people who are helping to make

FIG. 267. In a region like this, where there are plenty of plants, there are also plenty of animals.

your life more pleasant and easy. Farmers, storekeepers, miners, carpenters, iron-workers, glass-makers, bankers, and many others are doing things that help us. We need them, and they need us. It is easy to see the truth of the statement, "No one lives unto himself."

When we watch living things in the forest, the meadow, the sea, or other places, we find that they, too, live in communities. We find groups of plants and animals living together, each helping the other members of the community in some way.

Of course, the plants and animals that make up these communities do not plan their lives as men and women do. Each adult plant and animal must get what it needs. It must get food and water; it must have the right amount of light and heat to stay alive. In getting these necessities, the individual does not think of the welfare of other plants and animals. Plants and animals cannot think and plan their lives as we can. But, as you will see when you study this unit, certain kinds of living things must live together in order to keep alive.

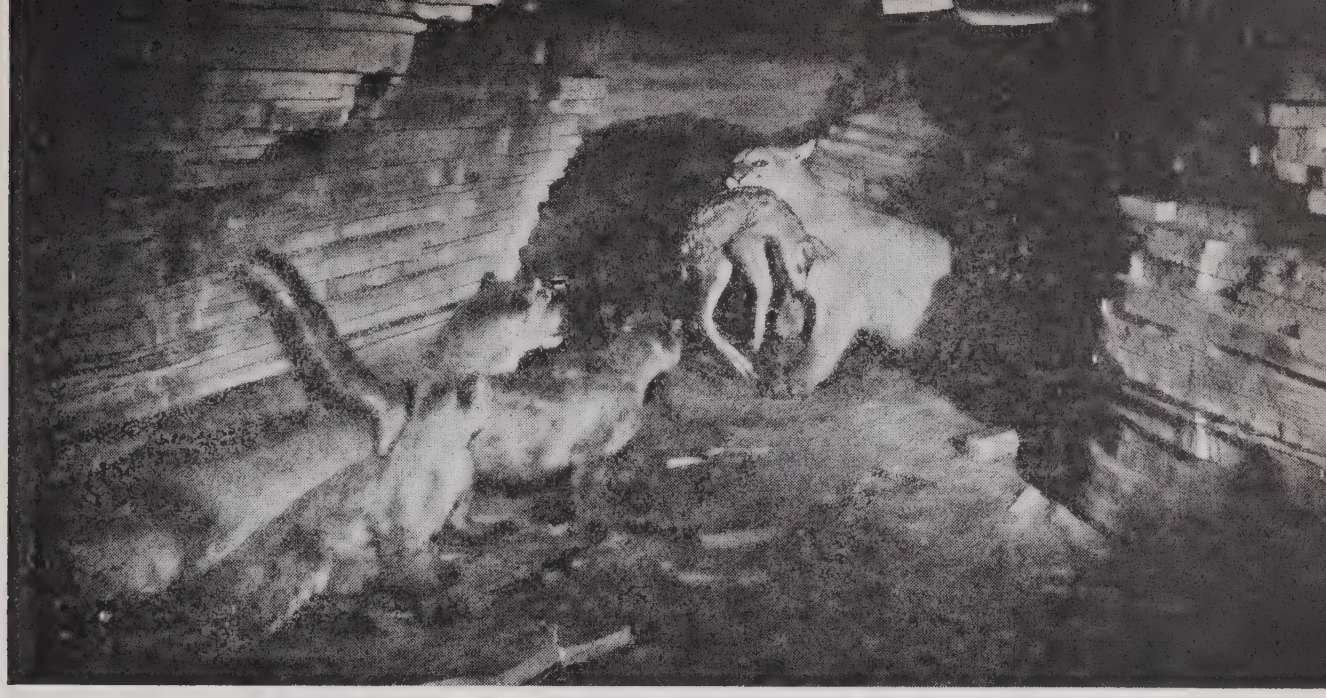


FIG. 268. Life among wild plants and animals is a constant struggle to stay alive. Every living thing must have food. The weaker plants and animals are destroyed in the struggle for food, air, water, and sunshine.

Along with this community life, in which living things are helping each other, there is also constant competition. Each plant and animal is struggling to keep alive. Cold, drought, heat, winds, and all the other forces of nature may make it hard for the animal or plant to live. Furthermore, each plant and animal must escape from or resist other living things that may try to eat it or its foods.

Life among wild plants and animals is always a struggle for existence. The strongest plants and animals live; the weakest die. There are no policemen or soldiers to protect the weak. Perhaps you have never thought about the struggle that is constantly going on in the world of living things. But if you keep your eyes open when you are out-of-doors, you can see this struggle almost everywhere around you. Suppose we take a walk in the woods to see what we can find.

Two dogs have just killed a rabbit and are fighting over it. Each dog is hungry and wants the rabbit for

food. A great commotion arises in the tree above our heads. A bluejay has tried to steal and eat the eggs from a robin's nest, and the robins are protecting the nest by driving the bluejay away.

A little farther on we find a woodbine and grape-vine both growing on the same dead tree. Once the tree was alive, but now it is dead, killed by the vines that strangled it and cut off its supply of light. Now the two vines are "fighting it out." Their roots are getting food materials and water from the same small plot of ground. If there is enough for both, they both will live. If not, the stronger vine will live, and the weaker will die.

FIG. 269. The grape-vine is using the tree to lift itself up into the air and light. At the same time it is robbing the tree of air and light.

Small insects, called leaf-hoppers, are sucking the sap out of a tree for food. Some caterpillars are eating all the leaves off a small tree. Here is a dead rabbit that was killed by small plants, called bacteria, living inside its body. Everywhere you look, you see living things struggling against their neighbors, fighting for food, light, and water to keep alive.

Life among the wild plants and animals is a curious affair. On the one hand, each living thing in some way helps other living things. On the other hand, each living thing is in constant competition with other living things in the struggle to stay alive. In the three problems that follow you will learn about some of the things that happen.

FIG. 270. This potter-wasp has killed spiders and put them in its nest. When the young wasps hatch, they will use the spiders for food. In this way the wasps are using the spiders.

Problem 1:

HOW DO PLANTS AND ANIMALS DEPEND UPON EACH OTHER?

WHY DO ALL LIVING THINGS DEPEND UPON GREEN PLANTS? In this problem you will study about a typical community of plants and animals. You will want to find out what kinds of living things make up such a community and how each kind of living thing helps to keep the community going. Of course, plant and animal communities are very different from each other, just as city communities differ from farming communities. But all plant and animal communities are alike in many ways. If you learn how they are alike, you will know how to study other communities of living things.

In every community of living things you will find plants and animals that use green plants for food. First, there is the great host of animals that feed only on plants. As you learned in Unit Nine, horses, cattle, elephants, sheep, and many kinds of insects and birds are some of the animals that use green plants for food. These are called

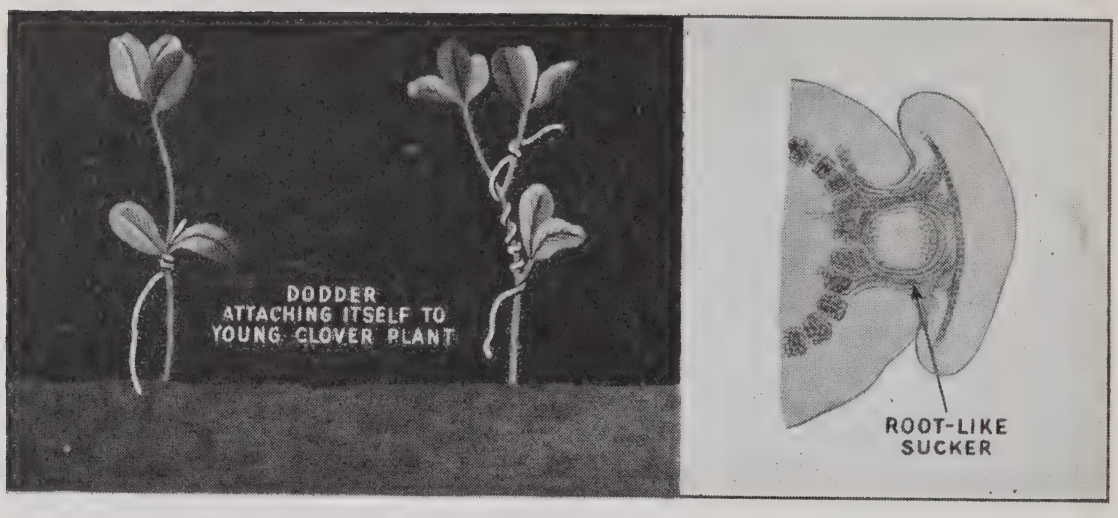


FIG. 271. This drawing shows how the dodder gets food from other plants.

herbivorous animals. They can change plant food into the kinds of materials of which their bodies are made.

Wherever you find herbivorous animals, you will also find carnivorous animals. These animals get their food by eating other animals. Many of the carnivorous animals cannot digest plant materials. For example, lions, tigers, wolves, owls, and hawks would starve if they tried to live on hay, corn, oats, and other plant food. Their digestive systems are not made so that they can digest plant materials. However, these animals can eat and digest animal materials. As you know, these meat-eating animals depend upon green plants for food, because they eat animals that eat green plants. If you trace back the food of any animal, including man, you will always come at last to green plants.

There are also many plants that get their food from green plants. (See page 332). Dodder, a common plant, has no chlorophyll. Its leaves are very small and yellow. Its seeds develop into new plants just as those of other seed plants do. When the upper stem of a dodder plant

touches another plant, it sends a root-like sucker into the plant. Through this sucker the dodder takes both food and water from the green plant on which it grows. Plants that get food or water from other living plants are called parasites. Dodder is a parasite because it takes food and water from a living green plant. A dodder plant may grow where its branches cannot touch a green plant. If this happens, the dodder soon dies because it cannot make its own food.

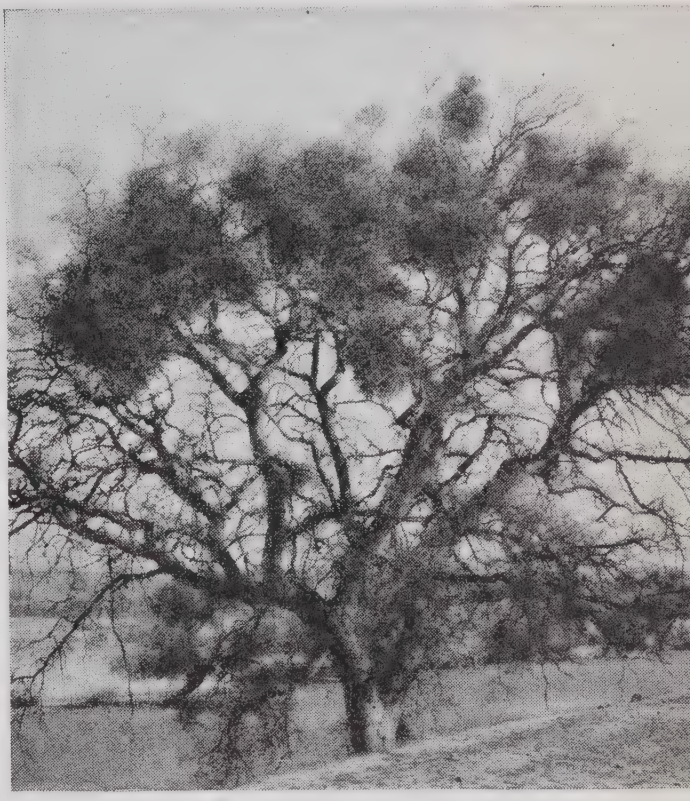


FIG. 272. When the mistletoe has killed this tree, the mistletoe, also, will die.

The mistletoe that grows on the branches of trees is partly a parasite. The leaves of mistletoe are green, and can manufacture food. But the plant gets water and minerals from the tree on which it grows. Then there are hundreds of kinds of rusts, mildews, and molds that grow on our corn, wheat, vegetables, and fruits. They are parasites, too. We fight them all the time because, in getting food for themselves, they destroy the plants that we need for food.

Wherever green plants grow, you will find other plants and animals that depend upon the green plants. They may use the plants for food, or they may eat the living things that feed upon the plants. All living things are supported by green plants.

FIG. 273. Our food plants soon take all the minerals from the soil because we harvest the plants instead of letting them die and decay. Therefore we have to put minerals back into the soil in the form of fertilizers.

HOW IS THE SUPPLY OF RAW MATERIALS KEPT UP? Imagine that you are in the country. As far as you can see, you are surrounded by green plants. Meadows, fields of crops, and forests around you have a population of millions of plants. Each of these green plants has roots that take minerals and water from the soil and leaves that take carbon dioxide from the air. For thousands of years green plants have used minerals from the soil and carbon dioxide from the air. Thus millions of tons of raw materials for food manufacture have been taken from the soil and the air.

It seems as if the supply of these materials must be inexhaustible. But this is not true. The minerals, carbon dioxide, and water must be returned to the soil and air, or the supply of these raw materials would soon be exhausted. Fortunately, nature has provided for this.

You can best see what happens if you go into a forest. In almost every forest you will find many fallen trees.

You will also find the ground covered with dead leaves, dead branches, and many small dead plants. These dead plants contain millions of pounds of materials that have been taken from the soil and air. Let us look for a tree that has been dead for many years and has fallen to the ground. The wood of this tree is very soft. You can easily kick a hole in it. Parts of it are so soft that you can crush it into fine powder with your fingers. What has happened to the wood? We say that it has *decayed or* rotted. What does this mean? What causes wood to decay?

Decay is a kind of chemical change; the material in the plant breaks up into simpler compounds or into its elements. This chemical change is brought about by bacteria and other tiny plants. These plants are helped by the oxygen in the air. What really happens is that such plants use the wood for food. In this process the wood is destroyed. The carbon in the wood passes back into the air in the form of carbon dioxide. The nitrogen in the wood is usually changed to ammonia, which also passes off into the air as a gas. A part of the wood is changed into water. Many of the minerals are left, and they, too, go

FIG. 274. This big tree, which grew up out of the soil, will slowly decay. As it decays, the materials that are in it will return to the soil and air.

back into the soil. In this way the materials that are locked in the bodies of plants all go back into the soil and air. Then new green plants can use them again to make food.

The bodies of dead animals also decay. In this way the elements and compounds in their bodies are returned to the soil and air. The whole process about which you have been reading is called the *food cycle*. A cycle is a series of events that repeats itself in the same order. This is what happens in the food cycle: (1) Raw materials from the soil and air are taken by the green plant and changed into food. (2) This food is used by other plants and animals to build up their bodies. (3) When the plant or animal dies, its body decomposes, and its materials go back to the soil and air. This completes the cycle, and the same series of events is repeated over and over again. Study the chart on page 385.

Now let us look at our community again. What are the groups of living things in the community? The first group is made up of the green plants that produce the food. The second group is the plants and animals that use the green plants for food. The third group is the bacteria that decompose the bodies of dead plants and animals and cause their materials to return to the soil and air. Each group contributes to the lives of the other groups in the community.

WHAT KINDS OF LIVING THINGS KEEP UP THE SUPPLY OF NITROGEN COMPOUNDS FOR PLANTS? You have learned that all plant and animal communities are alike in certain ways. In each community green plants are making food; animals and other plants are using this food, and food materials are constantly being returned

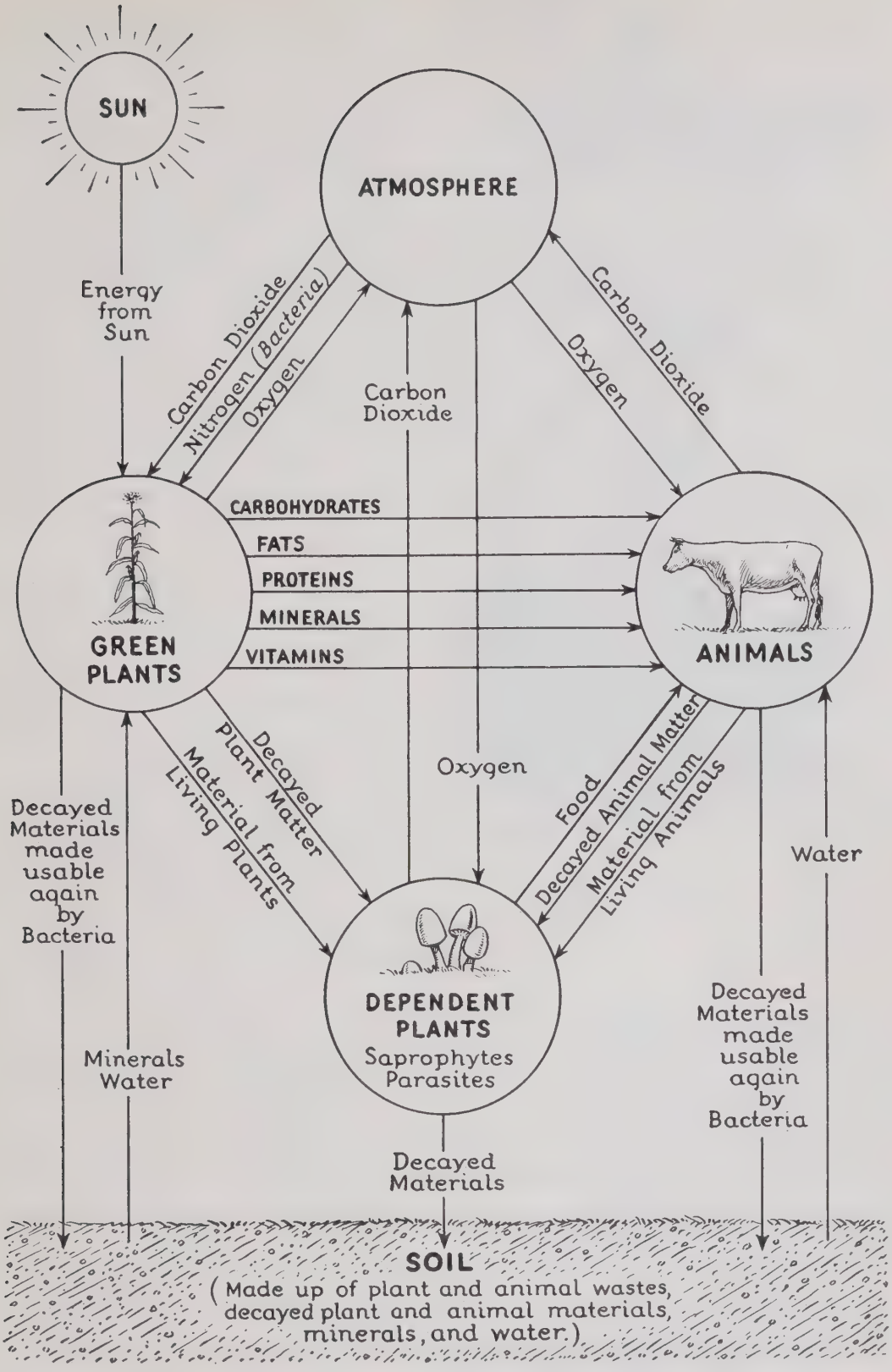


FIG. 275. The food cycle in nature. Study this diagram carefully and be ready to explain what it shows.

Fig. 276. Nitrogen *tubercles* on the roots of a clover plant

to the soil and the air when plants and animals decay. As you might expect, there are more complicated communities of living things than the one you have just read about. Let us discuss a community that includes the three groups already mentioned and also a fourth group.

One of the elements absolutely necessary for plant growth is nitrogen. Nitrogen, as you know, makes up about four-fifths of the air. Most plants, however, cannot use the nitrogen in the air. But nitrogen is also found in the soil. Here it is in the form of compounds known as *nitrates*. Plants can use the nitrogen in the soil because nitrates are compounds that can dissolve and go into the roots of plants. The result is that the supply of nitrates in the soil is gradually used up.

But there is one group of plants that are little nitrate factories. They are members of the bean family—alfalfa, clover, cow-peas, soy-beans—usually called *legumes*. These plants have formed an interesting and valuable partnership with a certain kind of bacteria. They can really take nitrogen from the air and put it into the soil. Let us think of a clover plant. From the soil some of the

bacteria enter the clover roots and produce little knots, or *tubercles*, on the root (Figure 276).

Here in the tubercles the bacteria have the unusual ability to take nitrogen from the air in the soil and manufacture compounds from it. The nitrogen compounds that they manufacture are used by the clover to make proteins. In return for this help the clover provides the bacteria with food and water. Both the clover and the bacteria profit from the partnership. Thus, in the community of living things these bacteria help animals and other plants by keeping up the nitrogen supply in the soil.

The discovery by scientists of this strange partnership has been of great value to farmers. Corn and other plants take a great deal of nitrogen from the soil. If they are planted in the same soil year after year, they use up most of the available nitrogen. As a result the crops grow poorer and poorer year by year. And that is exactly what has happened on many a farm. But the discovery of scientists supplied a remedy. They showed the farmer that soy-beans, clover, or other legumes should be planted every few years. In other words, the farmer *rotates* his crops. He plants crops that take nitrogen from the soil; then he plants crops that add nitrogen to the soil. When the clover is cut, the roots and tubercles that are rich in nitrogen compounds decay, and these compounds are added to the soil again. Sometimes the whole plant

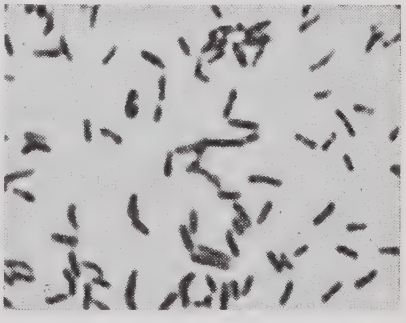


FIG. 277. The bacteria that make nitrogen compounds look like this under a powerful microscope.

FIG. 278. This farmer is growing soy-beans and corn together. What will the soy-beans do for the soil?

is plowed under. When this is done, a large amount of nitrogen is added to the soil. Our food supply depends to a great extent upon these bacteria that take nitrogen from the air and make it into compounds that green plants can use to manufacture food.

What you have just learned shows how important it is for man to know about the plant and animal communities of the world. When he understands how plants and animals help and harm each other, man can grow better and larger food crops. He can also find out how to protect the forests, wild flowers, and wild animals. The study of how living things affect each other is one of the most important parts of biology. This special kind of study is called *ecology*.

Self-Testing Exercises

1. Refer to Figure 275, page 385. Write a short essay explaining what the diagram shows.

2. What is a parasite? Why are dodder and mistletoe said to be parasites?

Problems to Solve

1. Select some carnivorous animal and trace its food back to the green plant.

FIG. 279. There are many different kinds of lichens. You can find them almost anywhere out-of-doors. Some of them are quite beautiful.

2. Show how a plant and animal community that includes bacteria that make nitrogen compounds is more likely to be prosperous than a community that has no such bacteria.

3. Show what effect man has on a plant and animal community when he comes to live there.

4. Suppose that it does not rain for a month or two. What effect will this have upon the plant and animal community?

5. Find out from some farmer what plan he uses in rotating his crops.

6. Find a clover, an alfalfa, or a soy-bean plant. Carefully dig it up and wash away the particles of soil that are clinging to the roots. Do you see anything about these roots that is different from other roots? If you are not certain whether you have found anything different, dig up some other kind of plant and compare the roots of the two plants.

7. Find out about the partnership in lichens. You can find lichens growing on rocks, trees, or fence posts. Look for brown, black, red, gray, or green patches. Bring some to class. Place them in a glass-covered box with a large well-moistened sponge. Set the box where it will receive some light, but not much direct sunlight. See if the lichens grow noticeably during a period of six weeks.

FIG. 280. The beaver is one of the most interesting animals to study. You would enjoy reading in some reference book about its wonderful skill in making homes and dams.

Problem 2:

HOW DO SOCIAL ANIMALS HELP EACH OTHER?

SOME animals live and work together for the good of all the other animals in the group. By banding together and forming a group or community, they can live better than if each animal lived alone. Such animals are called *social animals*. The simplest kind of social life among animals is found when they merely hunt or feed together in groups. Sheep, wolves, prairie-dogs, and fish are good examples.

Beavers have reached a much higher stage of social life. These industrious animals live in small groups near streams. They cut down trees with their sharp teeth and build dams to hold water about their homes. Sticks, stones, and mud are used in making their dams and homes. The homes are small hollow mounds built out in the water to keep other animals away. Here the beavers live and raise their families, each beaver working for the good of the whole group as well as for himself. Do you suppose a single beaver would be as successful in building a dam as a whole group would?

The highest stage of social life has been reached by such insects as wasps, bees, and some kinds of ants. Let us find how ants live and work together, for these insects are so common that everyone knows them. Ants live in large groups. Sometimes many thousands of them will be found in a single nest, or *colony*. These colonies are almost like little nations, for in them we find different classes of ants—queens (females), males that do no work, soldiers, and ordinary workers. The work is divided among the different classes, each class doing its share, as we shall see later.

The queen lays eggs, and the young are carefully tended through different stages until they are full grown. Then the young begin to work as the others do. An ant queen's life is spent mostly in the nest. The nest is in the ground, in dead wood, or in plant stems. As soon as the first workers are grown, the queen's only duty is to lay eggs. After many eggs develop into workers, some of the eggs grow into winged males and queens. When the ants with wings are grown, they leave the nest to form new colonies.

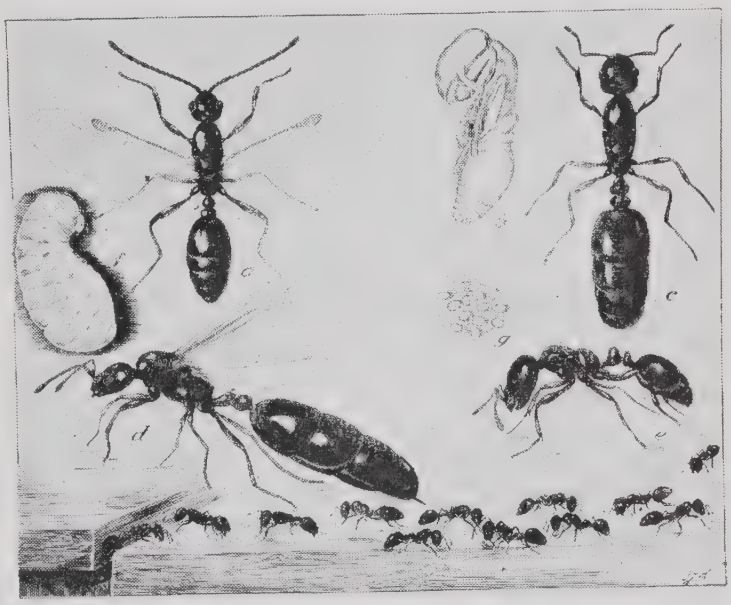


FIG. 281. Ants may seem all alike to you, but there are many different kinds, each kind with habits of its own. The picture shows different classes of black ants: (*a*) male, (*c*, *d*) females, (*e*) worker. A group of workers is shown in line of march.

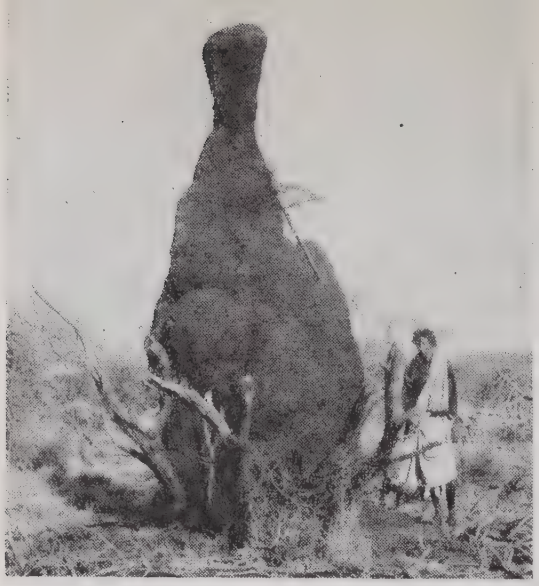


FIG. 282. This is the home one kind of termite builds for itself from bits of soil. Termites are often called white ants, but they are not ants.

Some ants, like the Amazon or warrior ants, actually go out on fighting expeditions and capture great numbers of other ants to work for them. If possible, the slave ants are captured while they are still too young to move. These helpless creatures are brought back to the ant nest and are cared for until they are grown. Then they become workers.

The driver ants of Africa, Asia, and South America are flesh-eaters. They go out on their hunt for food in long columns made up of millions of ants. Each ant in the long column is said to be as savage as any wild animal known. The ants kill and eat any living animal they can overtake. Even elephants and rhinoceroses leave as they approach.

In parts of our country there is a peculiar kind of ant, called honey-ant. Some of the worker honey-ants cling to the roof of their underground nest and serve as living storage casks for honey that the other workers have collected. Honey is stored in the abdomens, which become very large and rounded when filled with the honey. When other ants need food, they stroke the abdomens of these "storage creatures," and honey is given off to the hungry ones. Acting as storage casks is a strange kind of work, but in this insect colony "living storage creatures" seem to solve the problem of what to do with the extra supply of food.

FIG. 283. This picture shows you an ant "cow-herder" taking care of his "cows," the aphids.

Another kind of ant, the leaf-cutting ant, seems to be almost human in its method of getting food. These industrious little creatures actually grow crops of food in their underground homes. Some of the workers cut out pieces of leaves and carry them into their nests. Other workers pack the pieces of leaves into balls. On these balls there grows a tiny kind of *fungus*. This plant, which the ants eat, is somewhat like a mushroom. It can grow in the dark because it gets its food ready-made. These animals seem to be using a great deal of intelligence in dividing the work among different groups and in knowing how to cultivate plants for food.

Another kind of ant might be spoken of as "cow-herders." These ants capture many small insects of a certain kind and carry them into their nests. There the small insects, which are known as *aphids*, or plant-lice, lead a very easy life. Worker ants protect them and carry them to food plants; the aphids, in turn, must help the ants. When the ants stroke the bodies of these "ant cows," a peculiar sweetish fluid is given off. The ant then drinks this liquid. Small beetles and other kinds of insects also live in ants' nests.

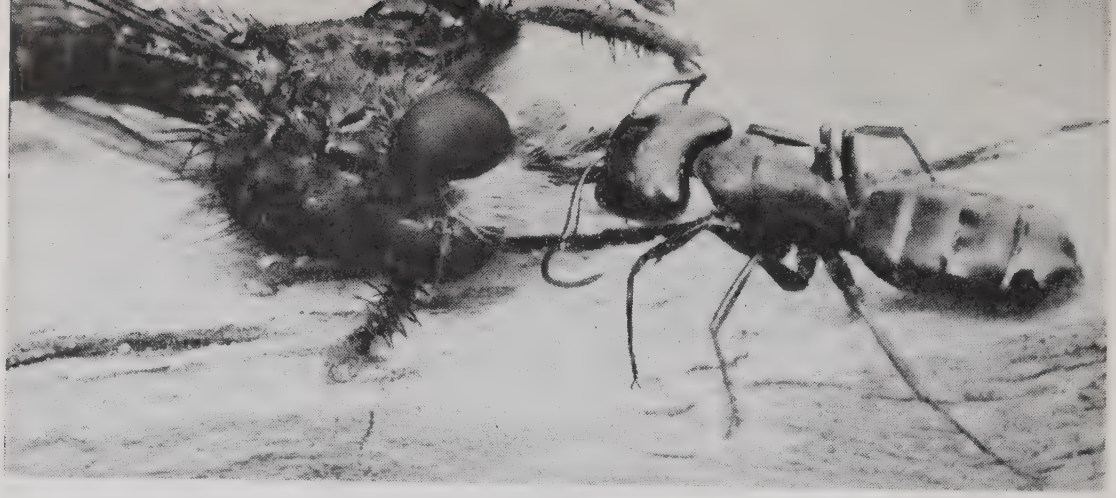


FIG. 284. This carpenter-ant has found a dead robber-fly and is dragging it home for food.

Two kinds of ants frequently found in this country are the common black ants and red ants. In most localities these ants may be found nesting in the ground in open fields, under rocks, and in other sheltered places. Very often black ants will make slaves of red ants, but sometimes a colony made up of both kinds of ants may be discovered living peacefully side by side under the same stone or log.

There is a very large kind of black ant that is often found under the bark of decaying trees. They are called carpenter ants because of the tunnels they make in decaying wood. Carpenter ants are very much larger than the common red and black ants; the queens are sometimes almost an inch long. Perhaps you have found some of these ants.

From this brief study of animals that live together in colonies, you can understand how a whole group of animals can live much more successfully than a single member could live by himself. They succeed because each individual attends to some part of the work. We say that there is a *division of labor* among the members of the colony. Do you think the name *social animal* is appropriate for them?

Self-Testing Exercises

1. Why is it an advantage for a beaver to live in a community of beavers? Give several reasons.
2. Give several examples to show that an ant works for the colony rather than for itself.
3. What do we mean by "division of work" among ants?
4. Explain in your own words why social animals can make a better living in groups than they can separately.

Problems to Solve

1. Compare the social life of beavers and ants. In what ways are these animals alike? In what ways are they different? Do you think that ants have reached a higher stage of social development than beavers? Why?
2. Compare the ways in which ants live and work together with the ways in which human beings live and work together.
3. Find out about the social life of bees.
4. Show how there is a division of labor in your own family.
5. In what way does division of labor benefit a colony?
6. When individuals live in a group in which there is division of labor, are the individuals less independent or more independent than individuals who live alone? Explain your answer.

Problem 3:
HOW IS THE BALANCE OF LIFE MAINTAINED?

UP TO THIS point you have been learning about plant and animal communities and communities of social animals. You have seen that each different member of the group does something useful for the whole community. Such communities are like our cities, in which the laborer, the storekeeper, the policeman, the cab-driver, and the milkman each helps the other people in the city. But you know that the people who carry on the same kind of business or occupation are not only helping each other;

they are also competing with each other. Each individual is competing with others for his share of business or work. This happens also in communities of plants and animals. Each plant and animal is competing with others in the struggle to keep alive. Let us now think about this contest between individual plants and animals.

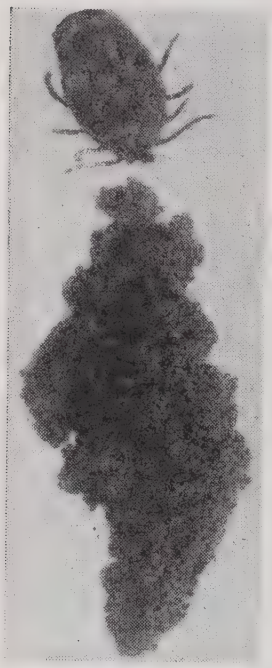


FIG. 285. This mass of thousands of eggs was laid by one little insect called the tick.

WHY IS THERE A STRUGGLE FOR EXISTENCE? First, let us consider some figures about the rate at which plants and animals reproduce themselves. A codfish may lay 9,000,000 eggs a year, about half of which become males and half of which become females. If all of the females lived and reproduced, at the end of the second year there would be 40,500,000,000,000 fish descendants from a single pair of codfish. At the end of the third year there would be 4,500,000 times as many fish as at the end of the second year. At this rate the ocean would soon be so full of codfish that there would be no room for water.

Now let us take some other examples. If nothing interfered, every pair of sparrows in the world would be the parents and grandparents of 275,716,986,698 birds in ten years. In a week's time a single one-celled animal and its offspring, like a bacteria or an amoeba, could produce enough of its kind to fill the oceans if they were allowed to multiply without interference. In a few weeks more a mass of these animals several times as large as the earth would be produced.

FIG. 286. Not all of these little swans will live to grow up into full-sized birds. Disease and enemies will destroy some of them.

If all the eggs laid by one female mosquito lived and reproduced, in three months' time the number of mosquitoes from this one female would be 102,914,592,864,480,008,004,001. When we think of what would happen if all the mosquitoes in the world grew to full size and reproduced at this rate, we can imagine what a calamity we would suffer.

Plants, too, can reproduce at a very rapid rate. Charles Darwin, the great British scientist, found that in a certain plot of land two by three feet 357 seeds developed into plants. He estimated that if all these plants and their descendants produced ten good seeds each, 3,500,000,000 plants would be produced in the tenth year. And they would need over 35,000 square miles in which to grow. Imagine, if you can, how many million square miles would be needed in ten years for the growth of all the seeds produced in the world each year!

The figures you have just read are truly amazing. They tell you how many plants and animals could be produced if they all lived and reproduced at a normal rate. Of course, we know that this does not happen.

If it did, the reproduction of all living things in a single year would cover every square foot of the earth's surface. As we look around us, we see that year after year there are about the same number of each kind of living things. Something must happen to prevent all of the young from growing up and reproducing.

Let us see what happens to the seeds of a plant. Even before seeds fall from a plant, large numbers of them are eaten by birds and other animals. The seeds that fall on the ground have a chance to grow. Many of them, however, fall on top of the ground and are eaten by birds. Others are covered with soil and are eaten by animals that live in the soil. Some seeds are blown away by the wind and finally fall in the water or in places where no plants can grow. Thus, only a few seeds from each plant ever get a real chance to grow into new plants.

Before seeds will grow, they must be warm and moist. Dry or freezing weather kills many of them when they are just beginning to grow. After they start growing, they must be able to get enough minerals and water from the soil as well as light from the sun. Fast growing seeds send their root systems into the soil quickly, and very soon they are taking in minerals and water. Such plants will send up their stems and leaves rapidly. Slow growing seeds will get a late start, and when their stems and leaves develop, they may be overshadowed by the faster growing plants. Those slower in developing die because of lack of light. Many plants thus die when they are very young.

The competition for minerals, water, and light goes on all the time. The strongest plants live; the weakest die. Many that win in the struggle with other plants

lose their lives when animals use them for food. Many of them are attacked by parasites and killed. Because of all these things, only a very, very small per cent of the seeds produced by plants ever grow into plants that produce more seeds. And so the number of plants is kept down by cold and dry weather, by the animal and plant parasites that use the plants for food, and by the constant struggle with other plants for water, minerals, and light.

FIG. 287. The struggles among living things to stay alive seem tragic to us, but they are all a part of nature's way of keeping a balance among the numbers of living things.

When we turn to animals, we find the same sort of story. A female frog lays thousands of eggs each year. Many of these are eaten by other animals. The eggs that grow develop into tadpoles. But tadpoles are attacked by leeches, water-bugs, fish, and birds. A few of the tadpoles develop into frogs, most of which will very likely be eaten by birds, fish, and snakes. Only a very small per cent of the frog's eggs ever develop into adult frogs that can lay more eggs. And so the number of frogs in a pond remains about the same year after year.

You can see now why there is a very real struggle for existence. More living things are produced each year than can possibly grow up. There is not enough space for growth; there is not enough food, water, and light

for all. Each plant and animal must get what it can. Whether or not it lives depends upon whether it is strong enough to get what it needs to stay alive. In the struggle many more living things die than live. It is a law of nature that he who lives must be able to get what he needs to keep himself alive. However, the social animals, such as ants, bees, beavers, and men, are better able to obtain the necessities of life because they help each other.

Self-Testing Exercises

1. Explain why there is a struggle for existence.
2. Explain why only a very small per cent of seeds and eggs grow into adults that reproduce.

HOW IS THE BALANCE OF LIVING THINGS BROUGHT ABOUT? Wherever you go on the surface of the earth, you find plants and animals living together. You have seen that in some ways plants and animals help each other. This happens in communities in which each kind of plant and animal in some way helps the life of the group. It also happens among the social animals. But there is also competition among the different members of the community for the necessities of life. In this struggle each member of the group is acting for himself and not for the other members of the group.

The situation is somewhat like our human society. We act as a group when we provide fire and police protection. We act as a group when different members perform different kinds of services for the whole community. In business, however, we act more or less as individuals. We start a store and compete with others in the same line of business. If we are successful, it may mean that others must fail. In any town there is only enough busi-

ness for a certain number of grocery stores. If too many are opened, some will fail; and finally only enough stores will be left to meet the needs of the community. Competition among business men limits the number of stores of the same kind in any community.

We have seen that more young plants and animals are brought into the world than can possibly grow up. This overproduction of young causes a struggle for existence. Out of this struggle for existence comes a *balance of numbers* among living things. What do we mean by a balance of numbers? We have a balance of numbers when just enough young plants and animals grow up to take the place of the old ones that die or are killed. Let us now see how the struggle for existence results in a balance of numbers.

FIG. 288. Most woodpeckers are very valuable to us because they help keep down the numbers of insects that destroy plants.

Let us suppose that for some unknown reason a certain kind of insect succeeds in producing an exceedingly large number of young. The insects will be a large supply of food for the birds that feed on them. Thus there will be food for a larger number of birds, and the number of birds will increase. As the number of birds increases, more and more of the insects will be eaten. As the insects get fewer and fewer, the birds will get fewer and fewer. Soon the number of insects and the number of birds will

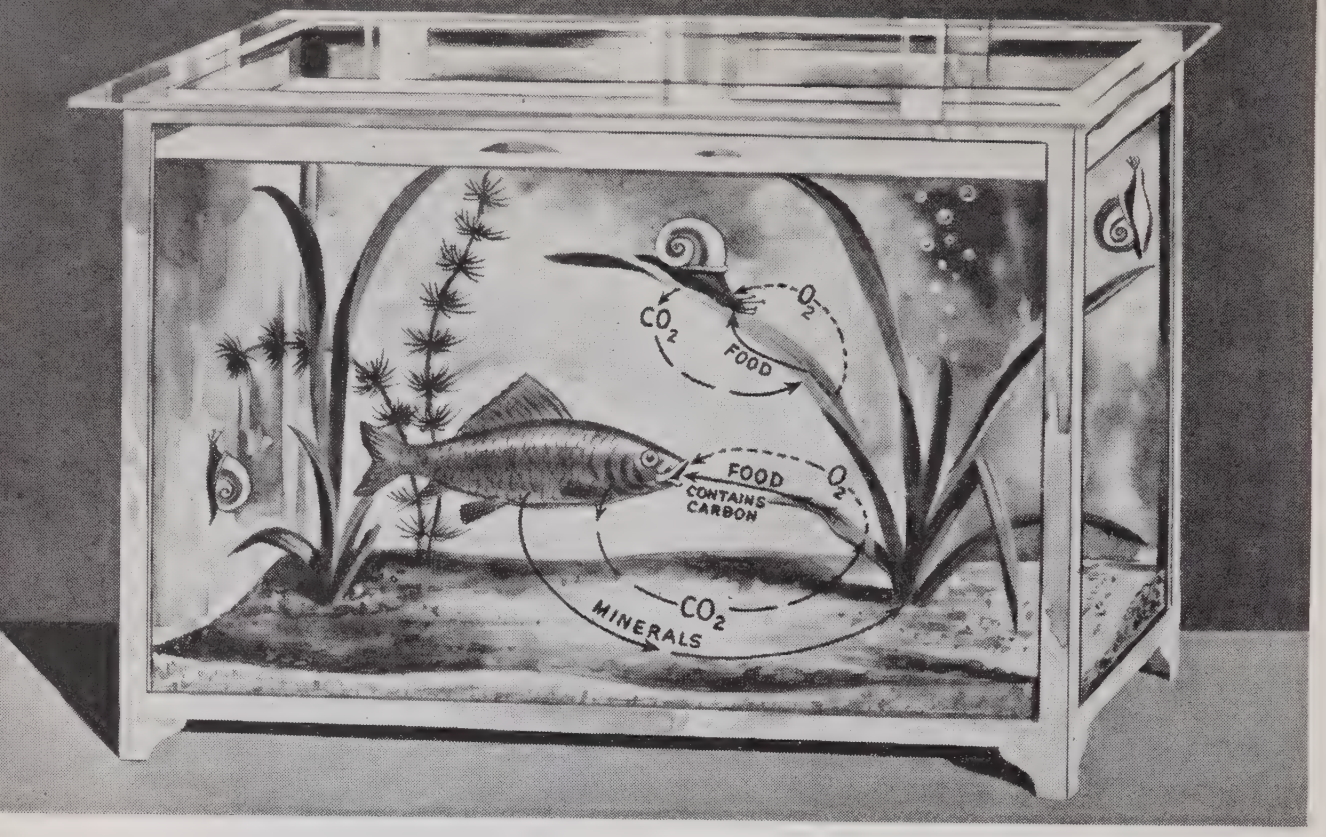


FIG. 289. A balanced aquarium, showing the oxygen-carbon-dioxide cycle. The animals breathe in oxygen and give out carbon dioxide. The plants take in carbon dioxide and give back oxygen to the water.

get back to normal. In other words, there will again be a balance of numbers.

This is a very simple illustration of what may happen. Yet you can see how the balance is brought about. An increase in the number of plants and animals makes possible an increase in the animals that use those plants and animals for food. Then there will be fewer of the food plants and animals to grow seeds and lay eggs. Therefore, there will not be so much food for the animals that prey on them, and the number of these animals will also decrease. So the situation comes back to normal again.

An interesting example of the balance between animals and green plants can be shown by arranging a balanced aquarium.

EXPERIMENT 51. *How Is a Balanced Aquarium Constructed?* A balanced aquarium can best be constructed with a rectangular glass aquarium tank having a capacity of six or more gal-

lons. Obtain some sand and thoroughly clean it in running water. Cover the bottom of the aquarium tank to a depth of about two inches. Fill the aquarium with faucet water that has stood in open containers for about a week, or with clear pond water. Pour the water on a piece of paper so that it will not stir up the sand. A few plants such as Vallisneria (tape grass), Sagittaria (arrowhead), Elodea, and Myriophyllum should then be planted.

Set the aquarium in a place where it can obtain direct sunlight for two or three hours a day. If the water becomes cloudy and the plants do not grow, reduce the number of plants. Allow the aquarium to stand for several days, and then add three or four snails, two or three tadpoles, four or five small fish, and a clam. Get mud minnows, catfish, or sticklebacks instead of goldfish, if you can. The water should remain clear. If it becomes cloudy, it should be changed, or the number of plants or animals, or both, should be decreased. The correct number of plants and animals must be determined by experimenting.

The animals should be fed sparingly. A few very tiny animals, such as cyclops, daphnia, and cypris, should be kept in the aquarium to serve as food. These can usually be obtained from pools by means of a fine-meshed net. In addition to this, a small quantity of fish food should be added each day.

By careful experimentation it is possible to make an aquarium that is in perfect balance. The aquarium may be sealed air-tight, and the plants and animals will continue to live. The green plants use water, carbon dioxide, and minerals to manufacture food. As they make food, they give off oxygen to the water. The animals eat the food made by the plants and breathe in the oxygen given off by them.

The animals give off carbon dioxide gas and wastes that contain minerals. The green plants use these materials to manufacture a new supply of food. Thus the process keeps going on and on. The number of living things in the aquarium is kept in perfect balance by the amount of food available. This same process goes on about us all of the time. The "give and take" between plants and animals keeps their numbers balanced.

FIG. 290. In Salt Lake City there is a monument in honor of the sea-gull. Sea-gulls saved the crops of the early settlers by eating grasshoppers that threatened to ruin the crops.

Occasionally the balance is upset; and when this happens, it is a very serious matter. For some unknown reason a certain animal will reproduce in tremendous numbers and will sweep the land. In Nevada in 1907 a mouse plague occurred. Countless numbers of mice appeared and destroyed over three-quarters of the alfalfa crop. The birds and other animals that feed upon mice had a busy season. We have also had numerous grasshopper plagues in this country. Hordes of grasshoppers have covered the land and destroyed almost every green plant in their path.

In plagues like these the mice and the grasshoppers are not reduced to the normal numbers by the animals that use them for food. There are not enough animals to eat the mice and the grasshoppers that are produced. If the plague is to be stopped, other things must happen to

reduce the number of harmful animals. The most effective destruction comes from disease germs. Other animals are like us in that they are attacked by germs that make them sick. When large numbers of animals are gathered together, these germs increase tremendously. They can travel easily from one animal to another, and an epidemic results. Animals die by the thousands. Scientists know of many cases where a plague of animals has been stopped by an epidemic among the animals.

Then, of course, if there are too many animals, they will soon use up all the food, and this lack of food will help to reduce the number to normal or even below normal. Unfavorable weather kills many animals, especially while they are young. Man may be helpless to stop plagues of destructive animals, but nature steps in, and at last the offending animals are again brought under control.

Self-Testing Exercises

1. What is meant by the term "balance of numbers"?
2. Close your book and try to make a drawing or diagram that shows how animals and green plants balance each other in a properly arranged aquarium. Explain your diagram carefully and clearly.
3. How are animals that cause a plague finally brought into balance? Mention several ways.

HOW DOES MAN DISTURB THE BALANCE OF LIFE? Whether you go into a plant and animal community or into a human community, you will find, over a long period of time, a state of balance. In learning about the balance of life in nature you must always remember that two things are happening side by side. Individual plants and animals are doing things that help the community as a whole, and individuals are competing with each other

FIG. 291. Years ago in our country there were great flocks of beautiful passenger pigeons. Man killed them in great numbers and cut down the forests where they made their homes. Today not one of these birds is left.

for the necessities of life. (Of course, they do not know that they are doing these things.)

Now let us imagine a region in which certain plants and animals have been living for hundreds or even thousands of years. The plants and animals will be those that are fitted to the kind of climate, soil, temperature, amount of water, and other conditions. Through years of cooperation and competition a state of balance of numbers will be secured. Year after year the same kinds of plants and animals will be found in about the same numbers.

Now man moves into this region. He cuts down part of the forests. He plows up the land and sows his crops. He destroys the plants that he does not want. He may kill the squirrels, rabbits, snakes, mice, and birds. He may bring in new plants and animals. What happens? In a few years he destroys the balance of nature. The new conditions that he provides may prove helpful to some kinds of living things. They will live and reproduce in greater numbers. But the new conditions may be harmful to other kinds of living things. They will be reduced in number until they finally disappear or nearly

disappear from the land. Man thus disturbs the natural balance of plants and animals, and great changes take place.

Let us see what has happened in a few cases where man has destroyed the balance of nature. About a hundred years ago an Englishman took a few rabbits to Australia. He hoped that they would multiply rapidly enough to provide a little hunting. They did! The rabbits had no natural enemies in Australia; so their numbers increased by leaps and bounds. They became a pest by destroying grass, vegetables, and trees. They were so destructive that the government of New South Wales offered $125,000 for a plan to get rid of them. So far no one has earned the reward. Rabbits are still a pest in Australia. Many instances can be found in which an animal, taken to a new country, upset the natural balance and became a pest.

Man has upset the natural balance in many other ways. The dust storms in the West are the result of plowing up the grass and destroying the tough roots that

FIG. 292. When man broke the tough, thick prairie sod with a plow in our western states, he ruined nature's covering for the dry, light soil. The soil could not hold moisture, and wind kept blowing the dry soil around. Therefore plants could not grow, and animals had no plants for food.

FIG. 293. Cottony-cushion scale. Find out how man learned to control this destructive insect.

would hold the moisture and keep the soil from blowing away. Destroying the forests has resulted in disastrous floods. Every change that man makes in nature has far-reaching effects. It is only in recent years that such things have been studied. Man must be very careful in disturbing the balance of life. If he disturbs the balance too greatly, he may bring about changes that will, in the end, do him serious harm.

Self-Testing Exercises

1. What is a "balance of life"?
2. When the balance has been disturbed by the appearance of too many animals of one kind, how is the balance restored?
3. Give some cases in which man has disturbed the balance of nature.
4. Explain why it may be dangerous to upset the balance of nature.

Problems to Solve

1. Explain why a plant or an animal may be very useful in one country and become a pest in another country.
2. In a place where man had never been, would a balance of life occur? Give reasons for your answer.

3. Find out how orange and lemon growers control the cottony-cushion scale that attacks their trees.

4. It is claimed that when new roads are opened up in a country, the number of fish in the streams and lakes decreases. How can you explain this?

5. Find out how forests at the head-waters of streams help to prevent floods.

LOOKING BACK AT UNIT ELEVEN—SUMMARY EXERCISES

1. Make a list of all the principles, or big ideas, of science that you have learned by studying this unit. Write each one in the form of a complete statement.

2. Show that you know the meaning of these science terms:

food cycle	*decay*	*tubercle*
rotates (crops)	*nitrates*	*ecology*
colony	*legume*	*social animal*

ADDITIONAL EXERCISES

1. In some good reference book find directions for setting up a terrarium in which plants and small animals live. You will need a large glass case like the one used for Experiment 51. Notice how easy it is to keep the plants growing without animals.

2. In a very dense forest we find few plants growing on the forest floor. Why?

3. Observe some kind of large tree near your home or school. Make a list of the animals and plants that depend upon this tree for food, shelter, support, or protection.

4. Find out how some insects help flowers to produce seeds.

5. In what ways has much of the bird life in this country been largely destroyed? What are some of the methods that are now being used to help preserve bird life?

6. Man is said to be an omnivorous animal. What does this mean?

7. Find some ants carrying on their usual activities on the ground or on plants. Notice how they behave toward each

other. See if you can find any of the plant lice or "ant cows" being cared for by the ants. If you can find an ant nest, look for the different classes of ants in the colony and the different stages in the development of the ants.

8. In a reference book find directions for building an ant nest. Build a nest and put in it a colony of ants. If you can, get a queen (larger than the other ants) so that there will be eggs for the colony. After the ants have become accustomed to their new home, watch them to see how they live and work together.

9. Find out why the earthworm is called the "living plow."

10. In reference books find material about the value of birds or insect destroyers. Report to the class what you find.

11. Read all you can find in reference books about ants, bees, or beavers. Report orally to your class or write a composition about the new things you learn.

12. Make as long a list as you can of the ways in which animals help plants.

13. Make as long a list as you can of the ways plants are harmful to animals (including man). Do not forget the plants that are parasites.

14. Does a balance of nature exist in a lawn? To solve this problem think what would happen if no one cared for the lawn for five years.

15. Does a balance exist in a vegetable garden? Solve this in the same way as in the preceding exercise.

16. How do you think a farm would change if left to nature for 100 years? Would it finally resemble the wilderness the early settlers found? Give reasons for your answers.

READINGS IN SCIENCE

This part of the book is to help you find interesting science reading outside your textbook. The *General Books* named below are books that have parts on a great many different scientific topics. Usually you can find what you want to read by looking for a topic or word in its alphabetical place or in the index.

The *Books on Special Topics*, beginning on page 412, are of many different kinds. Some of them are interesting to read all the way through. A few are on topics in which you may be interested but that are not discussed in this book. Some of these books will be most useful when you want to find out more about some special topic for your own satisfaction and for reports to your class. Others give directions for making things and doing experiments.

Probably you cannot find all these books in your school or public library, but almost every library will have some of those named or others very much like them. Ask your librarian how to look for them on the science shelf or in the card catalog of the library.

I. GENERAL BOOKS

Book of Knowledge (20 volumes). Grolier Society, 1931.
Book of Popular Science (16 volumes). Grolier Society, 1931.
Boy Scouts of America. The Official Scout Handbook for Boys.
Compton's Pictured Encyclopedia (15 volumes). F. E. Compton and Co., 1937.
Girl Scouts of America. The Official Scout Handbook for Girls.
World Book Encyclopedia (13 volumes). W. F. Quarrie and Co., 1934.

II. BOOKS ON SPECIAL TOPICS

Unit One: How Do Scientists Make Discoveries?

Burton, Charles P. *Moving the Earth.* Holt, 1936.

De Kruif, Paul H. *Men Against Death.* Harcourt, 1932.

De Kruif, Paul H. *Hunger Fighters.* Harcourt, 1928.

De Kruif, Paul H. *Microbe Hunters.* Harcourt, 1926.

Disraeli, Robert. *Seeing the Unseen.* Day, 1933.

Hylander, C. J. *American Scientists.* Macmillan, 1935.

Ilin, M. *Men and Mountains.* Lippincott, 1935.

Lansing, Marion F. *Great Moments in Science.* Doubleday, 1926.

Williams-Ellis, Amabel. *Men Who Found Out.* Coward-McCann, 1930.

Yates, Raymond F. *1,500 Needed Inventions.* Donley, 1936.

Yates, Raymond F. *Exploring with the Microscope.* Appleton-Century, 1934.

Unit Two: What Kind of World Do You Live In?

Bock, George E. *What Makes the Wheels Go 'Round.* Macmillan, 1931.

Collins, A. F. *The New World of Science.* Lippincott, 1934.

Daglish, E. F. *The Life Story of Birds.* Morrow, 1930.

Daglish, E. F. *The Life Story of Beasts.* Morrow, 1931.

Ditmars, Raymond L. *The Book of Living Reptiles.* Lippincott, 1936.

Duval, Elizabeth W. *This Earth We Live On.* Stokes, 1937.

Eisen, Edna E. *Our Country from the Air.* Wheeler, 1937.

Fitzhugh, Edward F. *Treasures in the Earth.* Caxton, 1936.

Ilin, M. *100,000 Whys.* Lippincott, 1933.

McCreery, J. L. *Exploring the World and Its Life.* Stokes, 1933.

Meister, Morris. *Living in a World of Science: Energy and Power.* Scribners, 1935.

Stephenson, Mary B. *The World of Animals.* Follett, 1930.

Washburne, Carleton and Heluiz. *The Story of Earth and Sky.* Appleton-Century, 1935.

Webster, Hanson H. *The World's Messengers.* Houghton, 1935.

Unit Three: What Is a Material?

Abbot, Charles G. *Everyday Mysteries.* Macmillan, 1923.

Meister, Morris. *Living in a World of Science: Heat and Health.* Scribners, 1931.

Meister, Morris. *Living in a World of Science: Water and Air.* Scribners, 1930.

Unit Four: How Do Heating and Cooling Change Materials?

GAIL, OTTO WILLI. *Romping Through Physics.* Knopf, 1934.
MEISTER, MORRIS. *Living in a World of Science: Heat and Health.* Scribners, 1931.
MEISTER, MORRIS. *Living in a World of Science: Energy and Power.* Scribners, 1935.
MOTT-SMITH, MORTON. *Heat and Its Workings.* Appleton-Century, 1933.

Unit Five: How Can One Kind of Substance Change into Another Kind?

ABBOT, CHARLES G. *Everyday Mysteries.* Macmillan, 1923.
BEALE, HARRIET B. *The Beginnings of Chemistry.* Coward-McCann, 1929.
COLLINS, A. F. *Experimental Chemistry.* Appleton-Century, 1930.
COLLINS, A. F. *The Boy Chemist.* Lothrop, 1924.
DARROW, F. L. *The Boy's Own Book of Science.* Macmillan, 1923.
HARROW, B. *The Making of Chemistry.* Day, 1932.
HAYES, ELIZABETH LE MAY. *What Makes Up the World.* Follett, 1930.
MCCREERY, J. L. *Exploring the World and Its Life.* Stokes, 1933.
MEISTER, MORRIS. *Living in a World of Science: Water and Air.* Scribners, 1930.
MEISTER, MORRIS. *Living in a World of Science: Energy and Power.* Scribners, 1935.
NEBLETTE, C. B., BREHM, F. W., AND PRIEST, E. L. *Elementary Photography.* Macmillan, 1936.
WILSON, SHERMAN R. *Descriptive Chemistry.* Holt, 1936.

Unit Six: How Do We Use and Control Fire?

FLOHERTY, J. J. *Fire Fighters: How They Work.* Doubleday, 1933.
HAYES, ELIZABETH LE MAY. *What Makes Up the World.* Follett, 1930.
MEISTER, MORRIS. *Living in a World of Science: Heat and Health.* Scribners, 1931.
WILSON, SHERMAN R. *Descriptive Chemistry.* Holt, 1936.

Unit Seven: How Do Magnets Work?

MEISTER, MORRIS. *Living in a World of Science: Magnetism and Electricity.* Scribners, 1929.
MORGAN, ALFRED P. *A First Electrical Book for Boys.* Scribners, 1935.
YATES, RAYMOND F. *How to Make Electric Toys.* Appleton-Century, 1937.

Unit Eight: How Are Plants and Animals Alike?

Daglish, E. F. *How to See Plants.* Morrow, 1932.
Disraeli, Robert. *Seeing the Unseen.* Day, 1933.
Stephenson, Mary B. *The World of Animals.* Follett, 1930.
Yates, Raymond F. *Exploring with the Microscope.* Appleton-Century, 1934.

Unit Nine: How Do Plants and Animals Get Food?

Crump, Irving. *The Boy's Book of Fisheries.* Dodd, 1933.
Daglish, E. F. *How to See Plants.* Morrow, 1932.
MacDougal, D. T. *The Green Leaf: The Major Activities of Plants in Sunlight.* Appleton-Century, 1930.
McGill, Janet. *The Garden of the World.* Follett, 1930.

Unit Ten: Why Do We Eat Different Kinds of Foods?

Benz, Francis E. *Pasteur, Knight of the Laboratory.* Dodd, 1938.
Cassady, Constance. *Kitchen Magic.* Farrar, 1932.
Downing, E. R. *Science in the Service of Health.* Longmans, 1930.
Lansing, Marion F. *Great Moments in Science.* Doubleday, 1926.
McFee, Inez N. *Food and Health.* Crowell, 1924.

Unit Eleven: How Do Plants and Animals Live Together?

Athey, Lillian C. *Along Nature's Trails.* American, 1936.
Daglish, E. F. *How to See Plants.* Morrow, 1932.
Ditmars, Raymond L. *The Book of Zoography,* Lippincott, 1934.
Grey Owl. *Sajo and the Beaver People.* Scribners, 1936.
Innes, W. T. *The Modern Aquarium.* Innes, 1932.
Kenly, Julie C. *The Astonishing Ant.* Appleton-Century, 1931.
McGill, Janet. *The Garden of the World.* Follett, 1930.
Mannix, Daniel P. *The Back-Yard Zoo.* Coward-McCann, 1934.
Mannix, Daniel P. *More Back-Yard Zoo.* Coward-McCann, 1936.
Medsger, Oliver P. *Nature Rambles: Spring.* Warne, 1931.
Medsger, Oliver P. *Nature Rambles: Winter.* Warne, 1932.
Medsger, Oliver P. *Nature Rambles: Summer.* Warne, 1932.
Medsger, Oliver P. *Nature Rambles: Autumn.* Warne, 1932.
Stephenson, Mary B. *The World of Animals.* Follett, 1930.
Stowell, Thora, and Burgess, Thornton W. *The Book of Animal Life.* Little, 1937.
Weed, Clarence M. *Insect Ways.* Appleton-Century, 1930.

SCIENCE WORDS

THIS is a list of the important science words in the book, with the pronunciation and the meaning of each one. The marked letters in parentheses are sounded according to the letters in the following list of sample words. The accented syllable is marked ′.

a at, can	ē be, equal	o̤ actor, second
ā came, face	ė her, certain	oi oil, point
ä far, father	e̤ towel, prudent	ou out, found
â all, ball	i it, pin	u up, but
ȧ ask	ī line, mine	ū use, pure
ã care, dare	o on, not	u̇ put, full
a̤ alone, company	ō more, open	ṳ̄ nature
ä̤ beggar, opera	ö to, move	t̤ picture
e end, bend	ô off, song	ŦH then, they

A single dot under ā, ē, ō, ö, or ū means that the sound is a little shorter and lighter, as in cot′tā̤ge, rē̤-duce′, gas′ō̤-line, in′tö, ṳ̄-ni′ted.

ab do men (ab-dō′men or ab′dō̤-men): the last of the three parts of an insect's body; the lower part of the human body.

al gae, singular **al ga** (al′jē, al′gä̤): water plants that can make their own food; most seaweeds are algae.

a moe ba, plural **a moe bae** or **a moe bas** (a-mē′bä̤, a-mē′bē or a-mē′bä̤z): a very small water animal.

an es thet ic (an-es-thet′ik): a substance that is used by doctors so that patients will feel no pain.

an thra cite (an′thra̤-sīt) **coal:** a hard coal that burns with very little smoke and flame.

aph id (af′id or ā′fid): a plant louse, a very small insect that lives on plants.

Ar is tar chus (ar-is-tär′kus): a Greek astronomer of the third century B.C., who thought that the earth revolved around the sun.

Ar is tot le (ar′is-tot-l): a famous Greek philosopher (384-322 B.C.).

ash: what remains of a thing after it has been burned; the minerals in a substance.

atom (at′o̤m): the smallest particle of which matter consists. Atoms make up molecules, next larger particles.

bacteria, singular **bacterium** (bak-tē′ri-ä̤, bak-tē′ri-um): very tiny living plants, some of which cause diseases, and others of which are useful.

beri-beri (ber′i-ber′i): a disease caused by a lack of a certain vitamin.

biology (bī-ol′o̤-ji): the science of life or living things.

bituminous (bi-tū′mi-nus) **coal:** a soft, easily crumbled coal that burns with much smoke and flame.

calorie (kal′o̤-ri): a unit for measuring the amount of heat; the amount of heat required to raise the temperature of one kilogram of water one degree centigrade or to warm one pound of water about four degrees Fahrenheit.

carbohydrate (kär-bo̤-hī′drāt): the class of food substances to which sugar and starch belong.

carbon (kär′bo̤n): the most abundant element in coal and charcoal. Graphite is a form of carbon.

carbon dioxide (kär′bo̤n dī-ok′sīd): a heavy, colorless, odorless gas made up of carbon and oxygen.

carnivorous (kär-niv′o̤-rus): refers to animals that eat meat.

cell: one of the small sections or units of which all animals and plants are made and which is formed of a small amount of living matter, called protoplasm.

centigrade (sen′ti-grād): indicates the scale on a thermometer that has 0° for the temperature at which water freezes and 100° for the temperature at which water boils.

chemical analysis (kem′i-ka̤l a̤-nal′i-sis): a process of separating a substance into the parts or elements of which it is made.

chemical change: a change that results in a new material or materials with different characteristics than the original material.

chemical composition: the make-up of a substance in which certain elements are always present and always in certain amounts.

chemical equation (ē̤-kwā′sho̤n): a chemical "sentence" that shows the materials used and the materials produced during a chemical change. A chemical equation is usually written with symbols, as $Hg+O \rightarrow HgO$ or $HgO \rightarrow Hg+O$.

chemistry (kem′is-tri): the science or knowledge of the composition of materials, that is, what they are made of and the laws that govern their changes when they combine with other materials.

chlo ro phyll (klō′rō-fil): the green coloring matter of plants.
clin i cal (klin′i-kəl) **thermometer:** an instrument used to measure body temperature.
col o ny (kol′ə-ni): a group of plants or animals of the same kind living or growing together.
combination: the kind of chemical change that results in the joining together of two or more elements to form a new compound.
com bus ti ble (kəm-bus′ti-bl): capable of taking fire and burning.
com po si tion (kom-pə-zish′ən): the make-up of anything.
com pound (kom′pound): a material that can be divided into two or more elements; a material formed by chemical combination of two or more elements.
con dense (kən-dens′): change from a gas to a liquid.
con tract (kon-trakt′): decrease in size.
con vec tion cur rent (kən-vek′shən kur′ənt): the movement of gases or liquids caused by unequal temperatures of different parts.
Co per ni cus (kō-pėr′ni-kus): a Polish astronomer who discovered that the earth and the planets move about the sun (1473-1543).

de cay (dē-kā′): a kind of chemical change brought about by bacteria and fungi.
de com po si tion (dē-kom-pō-zish′ən): the kind of chemical change that results in the separation of a compound into other compounds or into the elements that compose it.
dependent plant: a plant that does not make its own food, but lives on other living things or on dead things.
di ges tion (di-jes′chən): the process of changing foods so that they can be used by the body.
dis solve (di-zolv′): make a material liquid by putting in, or by being put into, a liquid; change a solid to liquid form by mixing it with a liquid.
dis til (dis-til′): change a liquid to a gas by heating and then change the gas back into a liquid by cooling it.
dis til la tion (dis-ti-lā′shən): the process of changing a liquid to a gas by heating and then changing the gas back to a liquid by cooling.

e col o gy (ē-kol′ə-ji): the study of the relationships between living things and their surroundings.
e lec tro mag net (ē-lek′trō-mag′net): a piece of soft iron made into a magnet by an electric current in a wire coiled around the iron.

el e ment (el′ē-mẹnt): a material that cannot be taken apart or separated into other materials.
en er gy (en′ėr-ji): power to act or work.
ep i der mis (ep-i-dėr′mis): 1. the outer layer of cells in plants. 2. the outer skin of animals.
Eu gle na (ū-glē′nä̤): a one-celled living thing that has the characteristics of both a plant and an animal.
e vap o rate (ē-vap′ọ̄-rāt): change to gas.
ex pand (eks-pand′): increase in size.

Fah ren heit (fä′rẹn-hīt): indicates a scale on a thermometer that has 32° for the temperature at which water freezes and 212° for the temperature at which water boils.
Far a day (far′ạ-dā), **Michael**: English chemist (1791-1867).
fat: a kind of food material made of carbon, hydrogen, and oxygen, that the body uses for energy and storage.
fi brous (fī′brus) **roots**: roots of nearly the same size that make up the root system of plants like corn, rye, and wheat.
force (fōrs): a push or pull that tends to set a body in motion, or to stop a body that is already moving, or to change the direction in which a body is moving.
for mu la (fôr′mụ̄-lä̤): an expression or abbreviation showing by symbols the chemical elements of a compound. The formula for water is H_2O.
Fraun ho fer, Jo seph (froun′hō′fėr, jō′zẹf): a German scientist who invented the spectroscope (1787-1826).
fric tion (frik′shọn): rubbing of one thing against another.
fuel value: the amount of energy furnished by a food.
fun gus, plural **fun gi** (fung′gus, fun′jī): a kind of plant without chlorophyll, such as mushrooms, molds, mildews.

Gal i le o (gal-i-lē′ō): a famous Italian scientist (1564-1642).
gas: the form of matter that has no definite size or shape.
germ (jėrm): a one-celled plant or animal, too small to be seen without a microscope, that lives as a parasite in our bodies and causes disease.
grav i ty (grav′i-ti): the force that draws all bodies toward the center of the earth, and thus gives them weight.
guard cell: one of a pair of tiny bean-shaped cells that open and close the stomata of a leaf to regulate the amount of water evaporating from the leaf.

he li um (hē′li-um): one of the elements, a light gas, discovered first in the sun by use of the spectroscope and later in the earth.
her biv o rous (hėr-biv′ọ̄-rus): refers to animals that eat plants.
hy phae, singular **hy pha** (hī′fē, hī′fą̈): tiny thread-like tubes of a plant, like bread mold, that get food for the plant.

in com bus ti ble (in-kọm-bus′ti-bl): not capable of being burned.

Jans sen, Zach a ri as (jan′sẹn or yän′sẹn, zäk-ä-rē′äs): the Dutch scientist who invented the compound microscope.

leg ume (leg′ūm or lẹ-gūm′): plants of the bean family like beans, peas, alfalfa, and clover. On the roots of most legumes there are little knobs with bacteria that can take nitrogen from the air in the soil and make compounds from it.
Lip per shey, Jo han nes (lip′ėr-shā, yọ̄-hän′ẹs): a Dutch spectacle-maker, who discovered that two lenses, used together, would magnify distant objects and form a telescope.

mag net ism (mag′net-izm): the characteristic of magnets that causes them to attract iron and steel.
mag net ite (mag′net-īt): a kind of iron ore that attracts iron and steel as a magnet does.
mat ter (mat′ėr): what objects are made of. Anything that has weight and fills some space. Matter includes all solid materials, liquid materials, and gases.
mer cu ric ox ide (mėr-kū′rik ok′sīd): a compound of the two elements mercury and oxygen.
mer cu ry (mėr′kụ̄-ri): one of the elements. Mercury is a metal that is liquid at ordinary temperatures.
min er al (min′ẹ-rạl): a compound like iron ore found in the earth by digging or mining; a compound of iron, calcium, etc., found in small quantities in our food and necessary for plant and animal growth.
mold (mōld): 1. a kind of fungus consisting of a woolly or furry plant growth, often greenish in color. Mold often appears on food or other animal or vegetable substances left too long in a warm, moist place. 2. a hollow form into which a liquid is poured to harden into a certain shape.
mo lec u lar the o ry (mọ̄-lek′ụ̄-lär thē′ọ̄-ri): belief of scientists that all kinds of matter are made of tiny moving particles, called molecules.

mol e cule (mol′e-kūl): the smallest particle into which a substance can be divided without chemical change.

natural material: a material just as it is found in, or on, the earth.
neu tral ize (nū′tra̤l-īz): overcome the effect of something. One poison sometimes neutralizes another.
ni trate (nī′trāt): a type of compound that contains nitrogen. Nitrates are one kind of mineral found in the soil and required by plants.
ni tro gen (nī′trō̤-jen): one of the elements. Nitrogen is a gas without color, taste, or odor that forms about four-fifths of the air.
nu cle us, plural **nu cle i** (nū′klē̤-us, nū′klē̤-ī): in biology, an active body within the cell of an animal or a plant, without which the cell cannot grow or divide.

ore (ōr): rock, dirt, or sand, containing some metal, or a compound of a metal, such as iron, copper, gold.
or gan (ôr′ga̤n): a part of an animal or plant fitted to do a certain thing.
ox i da tion (ok-si-dā′sho̤n): a kind of chemical change in which a material unites with oxygen to form one or more new materials.
ox ide (ok′sīd or ok′sid): a compound of oxygen and one other element.
ox id ize (ok′si-dīz): combine with oxygen.
ox y gen (ok′si-jen): one of the elements. Oxygen is a colorless, odorless gas that forms about one-fifth of the air.

par a site (par′a̤-sīt): a plant or animal that lives in, or on, the body of another living thing and takes its food from that living thing.
pel lag ra (pe-lag′ra̤): a disease caused by the lack of a certain vitamin.
pe tro le um (pē̤-trō′lē̤-um): an oily, dark-colored liquid, found in the earth, from which gasoline, kerosene, etc., are made.
pho to syn the sis (fō-tō̤-sin′the-sis): the chemical change by which green plants make starch from water, minerals, and carbon dioxide with the help of sunlight and chlorophyll.
pole: 1. either end of the earth's axis. 2. one of the places on a magnet where the force is strongest.
pro bos cis (prō̤-bos′is): the mouth parts of some insects, developed to great length for sucking, as the proboscis of a butterfly or a moth.

pro te in (prō′tē̤-in): a kind of food material, containing nitrogen in addition to carbon, hydrogen, and oxygen, that is used for making new protoplasm.

pro to plasm (prō′tō̤-plazm): the clear syrup-like material that is the living part of all plant and animal cells.

re volve (rē̤-volv′): travel in a circle or curve around a point as the earth revolves around the sun.

root-hair (röt′hãr): fine thread-like part that extends from the young parts of roots.

ro tate (rō′tāt): 1. turn around a center or axis as the earth rotates on its axis. 2. change in a fixed order as to rotate crops in a field by planting corn one year, clover the next year, then corn again, etc.

rust: 1. iron oxide, a reddish-brown material, formed on iron when it is exposed to air or moisture. 2. a mold-like plant parasite that lives on the stems and leaves of wheat and other crops.

sap ro phyte (sap′rō̤-fīt): a plant that gets its food from plants or animals that have died.

sense or gan (sens′ôr′gạn): an eye, ear, or other part of the body by which a person or an animal sees, hears, etc., or feels heat, cold, pain, etc.

social animals: animals, like beavers, bees, and ants, that live and work together for the common good of the group.

so di um chlo ride (sō′di-um klō′rīd): the chemical name for table salt, a compound made of two elements, sodium and chlorine.

sol id (sol′id): the form of matter that takes up a certain amount of space and keeps its shape.

so lu tion (sō̤-lū′shọn): a liquid in which another substance has been dissolved.

spec tro scope (spek′trō̤-skōp): an instrument for obtaining and examining the band of colors formed when a ray of light from any source is broken up.

spon ta ne ous com bus tion (spon-tā′nē̤-us kọm-bus′chọn): the bursting into flame of oily rags, coal in large piles, etc., because of the great heat produced by the uniting of oxygen with the material.

state of matter: form in which matter exists, that is, as a solid, a liquid, or a gas.

steth o scope (steth′ō̤-skōp): an instrument used by doctors to hear sounds in the body.

stim u lus, plural **stim u li** (stim′ū-lus, stim′ū-lī): something that brings about a response in a living thing; something that causes some part of a body to act.

sto ma, plural **sto ma ta** (stō′mą, stō′mą-tą): a small opening in the skin of a leaf, protected by guard cells.

struc ture (struk′ṭūr): the way the parts of a thing are put together.

sym bol (sim′bo̤l): the letter or letters that stand for an element or an atom of an element, as O for oxygen.

tap-root (tap′röt): the main root of a plant.

the o ry (thē′o̤-ri): an explanation based on observation and reasoning.

ther mo stat (thėr′mo̤-stat): an automatic device for regulating temperature.

thy roid (thī′roid) **gland:** a gland in the lower front part of the neck that is very important to health.

tu ber cle (tū′bėr-kl): a small, round knob, or swelling, on the roots of legumes.

ul tra-vi o let (ul′trą-vī′o̤-let) **rays:** certain invisible rays of the sun. Some ultra-violet rays help make vitamin D in the body; others cause sunburn.

u ni verse (ū′ni-vėrs): all the heavenly bodies and the vast spaces between them.

Van Leeu wen hoek, An ton (vän lā′vẹn-hůk, än′tōn): a Dutch scientist who discovered bacteria and many other very small things with microscopes that he made for himself.

vas cu lar (vas′kū-lą̈r) **bundles:** round bundles of long cells, running lengthwise of the stem of a plant. They carry water and minerals from the roots to the leaves, food down to the stems and leaves, and support the entire plant.

vein (vān): 1. a rib of a leaf. 2. one of the blood-vessels or tubes that carry blood to the heart from all parts of the body.

vi ta min (vī′tą-min): one of certain special substances in foods, needed in very small amounts to keep the body healthy. Vitamins are found especially in milk, butter, raw fruits and vegetables, and cod-liver oil.

Vol vox (vol′voks): a spherical living thing that has the characteristics of both a plant and an animal.

x-ray (eks′rā′): a special kind of invisible light used to locate breaks in bones, to examine teeth, to treat certain diseases, etc.

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